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AN ERGONOMIC ASSESSMENT OF LOOP SYSTEMS FOR TRAVELLERS WITH HEARING IMPAIRMENTS

Prepared for the
Transportation Development Centre
Policy and Coordination Group
Transport Canada
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December 1990

DON CA 1394

92-00987/

The contents of this report reflect the views of the authors and not necessarily the official view or opinions of the Transportation Development Centre of Transport Canada.

Un sommaire en français de ce rapport est inclus avant la table des matières.

Transport Canada / Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No.	2. Project No.	3. Recipient's Catalogue No.
TP 10765E	6989	

4. Title and Subtitle

An Ergonomic Assessment of Loop Systems for Travellers with Hearing Impairments

5. Publication Date

December 1990

6. Performing Organization Document No.

7. Author(s)

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8. Transport Canada File No.

D1450-103-60

9. Performing Organization Name and Address

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10. DSS File No.

11SD.T8200-7-7512-C

11. DSS or Transport Canada Contract No.

T8200-7-7512/03-SD

12. Sponsoring Agency Name and Address

Transportation Development Centre (TDC)
200 René Lévesque Blvd. West
Suite 601, West Tower
Montreal, Quebec H2Z 1X4

13. Type of Publication and Period Covered

Final, December 1990

14. Project Officer

Ling Suen

15. Supplementary Notes (Funding programs, titles of related publications, etc.)

Funded under the Transportation of Disabled Persons Program (TDPP) of Transport Canada

16. Abstract

The purpose of this study is to review and consolidate existing information on assistive listening devices, particularly loop systems, and to outline a methodology for the testing and development of such systems for application in transportation terminals.

To satisfy the objectives of the study, an ergonomic analysis of the information requirements of travellers with hearing impairments was undertaken. A task analysis of the travel process revealed decision-making processes in which only auditory information is currently provided, creating difficulties for the hard-of-hearing traveller, and indicating potentially useful applications for loop systems. Focus group discussions with users were conducted and these supported the results of the task analysis, in addition to identifying the type of information that could be conveyed and the areas where loop systems might be most useful. The focus group discussions also revealed decision points where terminal signage was inadequate and should be supported by auditory information from an assistive listening device. The three main areas of application were the check-in counters, the waiting areas, and at the boarding gates.

System design, implementation and operational requirements were identified and discussed; and the report concludes with recommendations for the implementation, demonstration and testing of assistive listening devices for application in transportation terminals. The technology is available and, with the involvement of appropriate interest groups, could be easily demonstrated with a view to standardizing the application of these systems.

17. Key Words	18. Distribution Statement
Transportation, physically handicapped, elderly, disabled, information systems	Limited number of copies available from the Transportation Development Centre

19. Security Classification (of this publication)	20. Security Classification (of this page)	21. Declassification (date)	22. No. of Pages	23. Price
Unclassified	Unclassified	--	70	--

Transports Canada / Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. N° de la publication de Transports Canada	2. N° de l'étude	3. N° de catalogue du destinataire
TP 10765E	6989	

4. Titre et sous-titre
An Ergonomic Assessment of Loop Systems for Travellers with Hearing Impairments

5. Date de la publication
Décembre 1990

6. N° du document de l'organisme exécutant

7. Auteur(s)
Tom Geehan, Anne-Kristina Arnold et Ulrika Wallersteiner

8. N° de dossier — Transports Canada
D1450-103-60

9. Nom et adresse de l'organisme exécutant
TransVision Consultants
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Ergo Systems Canada
535 Robin Hood Road
West Vancouver
(Colombie Britannique)
V7S 1T4

10. N° de dossier — ASC
11SD.T8200-7-7512-C

11. N° de contrat — ASC ou Transports Canada
T8200-7-7512/03-SD

12. Nom et adresse de l'organisme parrain
Centre de développement des transports (CDT)
200 ouest, boul. René-Lévesque
Tour ouest, suite 601
Montréal (Québec) H2Z 1X4

13. Genre de publication et période visée
Final décembre 1990

14. Agent de projet
Ling Suen

15. Remarques additionnelles (Programmes de financement, titres de publications connexes, etc.)
Financé au titre du Programme de transport des personnes handicapées (PTPH) de Transports Canada.

16. Résumé

La présente étude a eu pour objet de passer en revue et d'enrichir la documentation connue sur les systèmes de sonorisation assistée, notamment ceux organisés en boucle, et de proposer une méthodologie pour l'essai et la mise au point de tels systèmes dans la perspective de leur implantation dans les installations terminales.

Elle a commencé par une analyse ergonomique des besoins d'information des voyageurs malentendants. L'analyse des étapes obligées d'un déplacement quelconque a révélé des moments critiques dans ce processus où l'information nécessaire est fournie sous forme exclusivement auditive, d'où les difficultés auxquelles se heurtent les voyageurs malentendants et que les systèmes d'information auditive en boucle promettent de réduire. Des entrevues avec des groupes cible ont permis de confirmer les résultats analytiques, de cerner la nature de l'information à transmettre et d'identifier les créneaux où les systèmes en boucle seraient de la plus grande utilité. Ces entrevues ont également mis le doigt sur les insuffisances de la signalisation visuelle en place, notamment aux endroits de transition, et sur la nécessité d'une information auditive complémentaire à être transmise par l'interméolaire d'une sonorisation assistée. Les trois endroits qui devraient en être équipés sont les comptoirs d'enregistrement, les salles d'attente et les portes d'embarquement.

La recherche s'est intéressée à la conception de systèmes en boucle, à leur implantation et à leurs fonctionnalités. Le rapport propose que soient implantés, éprouvés et essayés des appareils de sonorisation assistée dans les installations terminales. Non seulement la technologie est maîtrisée, mais, avec le concours des groupes intéressés, il sera facile de la mettre en oeuvre et d'uniformiser l'implantation des systèmes correspondants.

17. Mots clés	18. Diffusion
Transports, handicapés physiques, personnes âgées, handicapés systèmes d'information.	Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

19. Classification de sécurité (de cette publication)	20. Classification de sécurité (de cette page)	21. Déclassification (date)	22. Nombre de pages	23. Prix
Non classifiée	Non classifiée	—	70	—

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the advice and assistance provided to the project team by the Transportation Development Centre and by the following individuals and organizations:

Marian Rosenberger, Audiometric Technician, Doug Clifton, Supervisor, Technical Aids Department, and Maryalyce McDonald, Audiologist, Western Institute for the Deaf and Hard of Hearing, Vancouver, B.C.

Janet Albright, Audiologist, Let's Talk, Seattle, Washington

Eric MacIntosh, Consultant, White Rock, B.C.

Self Help for the Hard of Hearing, Bethesda, Maryland

Oval Window Audio, Yarmouth, Maine

Canadian Center for the Hard of Hearing, Toronto, Ontario

National Association for the Deaf, Seattle, Washington

Val Bedard, Canadian Hard of Hearing Association, Coquitlam B.C.

This project was funded under the Transportation of Disabled Persons Program (TDPP) of Transport Canada.

SUMMARY

The rate of participation of millions of hard-of-hearing people in personal/social, vocational, educational, cultural and recreational activities is accelerating. Contributing to the changing lifestyles of these individuals are the hearing-impaired themselves, others who communicate with them, health care professionals and manufacturers who develop and build assistive listening devices utilized by individuals with hearing loss.

Assistive listening devices include sound reinforcement equipment specifically designed to facilitate better understanding of speech by persons who are hard of hearing. All systems have one function in common: to bypass the acoustical space between the sound source and the listener. This space comprising reflected sound energy and noise prevents persons with hearing impairments from achieving an acceptable sound reception. The original sound diminishes in intensity as it leaves the source and, by the time it reaches a listener, it is masked by other reflections and ambient noise.

When sound (speech or music) is taken directly from the source to the ear of the listener, the result is better amplification and clarity of the desired sound with less background noise. Assistive listening devices include magnetic induction loops, infrared light beams, AM and FM wireless broadcast systems. The close, wireless coupling between microphone and ears produced by these systems provides a marked improvement in the discrimination of speech.

The purpose of this study is to review and consolidate existing information on assistive listening devices, particularly loop systems, and to outline a methodology for the testing and development of such systems for application in transportation terminals.

To satisfy the objectives of the study, an ergonomic analysis of the information requirements of travellers with hearing impairments was undertaken. A task analysis of the travel process revealed decision-making processes in which only auditory information is currently provided, creating difficulties for the hard-of-hearing traveller, and indicating potentially useful applications for loop systems.

Focus group discussions with users were conducted and these supported the results of the task analysis, in addition to identifying the type of information that could be conveyed and the areas where loop systems might be most useful. The focus group discussions also revealed decision points where terminal signage was inadequate and should be supported by auditory information from an assistive listening device. The three main areas of application were the check-in counters, the waiting areas, and the boarding gates.

Various assessments and field tests indicated that the loop system is the most technically suitable for airport terminal applications and the most acceptable system for users. Canada has the opportunity to be a leader in the use of loop systems in terminals and to set an international example.

System design, implementation and operational requirements of loop systems were identified and discussed; including the shape and strength of loops, magnetic field distribution, impedance and amplifier requirements, and testing and operating guidelines. It was noted that implementation by a qualified audiometric technician is a relatively simple operation.

The report concludes with a recommendation for the immediate implementation, demonstration and testing of assistive listening devices in transportation terminals, especially at check-in counters, waiting areas, and boarding gates of airport buildings.

SOMMAIRE

C'est par millions et à un rythme qui va s'accélérant que les malentendants participent aux activités sociales, professionnelles, culturelles et récréatives du milieu dans lequel ils vivent. Ils se sentent appuyés dans ce nouveau style de vie par leur entourage, les professionnels de la santé et les entreprises qui fabriquent les appareils de sonorisation assistée destinés à compenser les pertes auditives.

Les appareils de sonorisation assistée sont des appareils d'amplification des sons conçus exprès pour aider les malentendants à surmonter leur handicap. Ils ont pour fonction unique d'abattre la barrière acoustique qui sépare le locuteur du malentendant. Les sons réfléchis et les bruits ambiants qui constituent cette barrière empêchent une réception acceptable du message par les déficients auditifs. Comme les sons émis par le locuteur faiblissent avec la distance, les sons réfléchis et autres parasites les masquent avant même qu'ils ne parviennent au sujet.

Lorsque les sons (paroles ou musique) sont transmis directement à l'oreille du sujet, il en résulte une amplification améliorée qui permet une plus grande intelligibilité et une plus grande clarté des sons. Les appareils de sonorisation assistée transforment l'énergie acoustique émise en énergie magnétique, infrarouge ou radioélectrique en modulation d'amplitude ou de fréquence. En réalisant la transmission des sons directement et sans fil entre le microphone et l'oreille, ces appareils apportent une intelligibilité nettement améliorée de la parole.

La présente étude a eu pour objet de passer en revue et d'enrichir la documentation connue sur les systèmes de sonorisation assistée, notamment

ceux organisés en boucle, et de proposer une méthodologie pour l'essai et la mise au point de tels systèmes dans la perspective de leur implantation dans les installations terminales.

Elle a commencé par une analyse ergonomique des besoins d'information des voyageurs malentendants. L'analyse des étapes obligées d'un déplacement quelconque a révélé des moments critiques dans ce processus où l'information nécessaire est fournie sous forme exclusivement auditive, d'où les difficultés auxquelles se heurtent les voyageurs malentendants et que les systèmes d'information auditive en boucle promettent de réduire.

Des entrevues avec des groupes cible ont permis de confirmer les résultats analytiques, de cerner la nature de l'information à transmettre et d'identifier les endroits où les systèmes en boucle seraient de la plus grande utilité. Ces entrevues ont également mis le doigt sur les insuffisances de la signalisation visuelle en place, notamment aux endroits de transition, et sur la nécessité d'une information auditive complémentaire à être transmise par l'intermédiaire d'une sonorisation assistée. Les trois endroits qui devraient en être équipés sont les comptoirs d'enregistrement, les salles d'attente et les portes d'embarquement.

Tant les expérimentations que les essais sur place ont montré que les systèmes en boucle étaient les mieux adaptés techniquement aux aérogares, et qu'ils étaient les mieux acceptés par les voyageurs concernés. Le Canada devrait y voir une bonne occasion pour prendre les devants et devenir un exemple à suivre par le reste du monde.

La recherche s'est ensuite intéressée à la conception de systèmes en boucle, à leur implantation et à leurs fonctionnalités; elle en a abordé les divers aspects techniques comme la forme et la puissance de transmission des boucles, la répartition du champ magnétique, l'impédance et autres caractéristiques des amplificateurs, le type d'essais à effectuer et les notices concernant le mode de fonctionnement. Il a été noté que leur implantation par un technicien en audiométrie était une affaire relativement simple.

Le rapport de recherche propose l'implantation, l'essai et l'exploitation expérimentale immédiats d'appareils de sonorisation assistée dans les installations terminales et surtout aux comptoirs d'enregistrement, dans les salles d'attente et aux portes d'embarquement des aérogares.

TABLE OF CONTENTS

1. **INTRODUCTION** 1
   - Difficulties Experienced 2
   - Towards a Solution: ALDs 2
   - Communications Access 4

2. **IDENTIFICATION** 5
   - Audio Induction Loop 6
   - Infrared Light System 7
   - AM Radio Broadcast 8
   - FM Radio Broadcast 9

3. **ASSESSMENT** 11
   - Sound Transmission 13
   - Sound Reception 14
   - User Requirements 15
   - System Requirements 16
   - Potential Systems 17

4. **APPLICATION** 19
   - Basis for Understanding 20
   - Existing Systems/Deficiencies 21
   - The Users' Experience 27
   - Applications Testing 32
   - Proposed Applications 36

5. **REQUIREMENTS** 39
   - Loop Design Requirements 40
   - Testing Requirements 49
   - Operating Guidelines 49

6. **CONCLUSIONS** 51
   - Getting Started 52
   - Proposed Applications 52
   - Implementation Strategy 53

LIST OF EXHIBITS

1. Induction Loop System 6
2. Infrared System 7
3. AM Radio System 8
4. FM Radio System 9
5. Comparison of Assistive Listening Systems 12

6. Map of the Vancouver International Airport 22
7. Information Systems at the Airport 23
8. Task Analysis for Travelling in Airports 24
9. Task Analysis for Attending Travellers in Airports 26
10. Testing of the Loop System at Vancouver Airport 33

11. Testing of the Loop System at the Boarding Gates 34
12. Testing of the Loop System near Baggage Retrieval 35
13. Testing of the Loop System near the Customs Area 36
14. Current and Power for Loops of Various Shapes 41
15. Field Distribution for Different Height Induction Loops 42

16. Effect of Displacement on Power Needs 42
17. Field Distribution Across the Induction Loop 43
18. Null and Overspill 43
19. Wiring a Loop in Series for Multiple Turns 44
20. Resistance of Some Common Wires 45

21. Audio Induction Loop Design Chart 47
22. Series and Parallel Connection to an Amplifier 48
23. Field Strength (Magnetic Flux) Meter 49

1. INTRODUCTION

Any consideration of people with hearing impairments must include not only people with profound, almost total deafness but also those with a minimal, inconveniencing loss. Approximate numbers of individuals in Canada are:

Mild to moderate losses	*1,395,000*
Moderate to severe losses	*939,000*
Severe to profound losses	*201,000*
Total with hearing impairments	***2,535,000***
Hearing aid users	*400,000*

People with hearing impairments have varying capabilities, but they share a common problem -- difficulty in communicating. For people with profound losses, the communication problem is constant and interferes dramatically with their functioning. People with severe to profound losses may have to rely on lip reading or sign language to communicate. People with moderate to severe losses may rely on hearing aids to improve their communication abilities. For those with mild to moderate losses, communication problems can still result in extreme annoyance and frustration in a world which depends on communication, especially in areas like transportation terminals with high background noise.

Advances in technology have afforded the hearing health care professional an array of devices that can help hearing rehabilitation. Developments, from sophisticated hearing aids and cochlear implants to versatile assistive listening devices, continue to upgrade communication possibilities.

Transportation terminals also continue to improve their facilities and services for persons with disabilities. In terms of communication devices specific to the deaf and hard-of-hearing listener and 'sensitivity' training for personnel, airports are highly rated, but further efforts are needed.

DIFFICULTIES EXPERIENCED

Despite the efforts of the hearing-impaired themselves, hearing health care professionals and the manufacturers of sophisticated hearing aids, communication problems can still result in extreme annoyance and frustration in a world which depends on communication -- especially in the noisy, transient environment of a transportation terminal.

Difficulties still exist. The majority of communicative complaints center around situation-specific hearing difficulties where the individual experiences difficulty in crowded or noisy situations as when listening in groups, communicating over the telephone or conversing in a reverberant or noisy environment, situations where a typical hearing aid would be of minimal benefit to the listener.

In transportation terminals, levels of background noise and reverberation which may be only mildly disturbing to many people can completely obliterate speech understanding for one who suffers hearing loss. A hearing aid is likely to be overloaded and produce distortion from the relatively high volume settings of even high quality public address systems. As a result, deaf and hard of hearing people often find using terminals frustrating and confusing.

TOWARDS A SOLUTIONS: ALDS

Assistive listening devices (ALDs) may be the key to unlocking the potential marketplace by providing the benefits of amplification to a wider segment of the hearing-impaired population and by supplementing the performance of traditional hearing aids in difficult listening situations. The term assistive listening device has been used to describe hearing assistance equipment that has been designed to improve the communication of people with hearing impairments in specific listening situations especially where background noise or distance between the speaker and listener may degrade the integrity of the message.

Assistive listening devices also include alerting and signalling devices which are used to increase sound awareness or act as warning systems for the hearing impaired. Large area assistive listening systems, which are used in churches, theatres and auditoriums, serve the same purpose as personal assistive listening devices but on a much larger scale by delivering the speaker's message directly to the listener's ears or hearing aids, thus bypassing the acoustical distortions in the transmission path.

The ALD Advantage

Listening in auditoriums, restaurants and places of worship often presents a difficult acoustic burden to the hearing-impaired individual. The debilitating effects of room noise and reverberation on speech intelligibility has been shown to have a greater effect on the hearing-impaired individual than normal hearing

listeners. It has been estimated that the hearing-impaired individual requires about a 15 dB increase in the speech-to-noise ratio over the competing background sounds to achieve the same intelligibility score as a normal hearing person. The recommendation of an ALD to supplement an individual's hearing aid may offer the compensation necessary to function more effectively in these difficult listening situations allowing the listener to obtain greater social benefit from the use of amplification.

The acoustic advantage provided by assistive listening devices over that of a conventional hearing aid can be attributed to their dedicated design. Telephone amplifiers, FM radio and induction loop systems are some examples of such assistive devices which are designed to maximize hearing efficiency in specific listening situations by amplifying the selected sound source over that of extraneous or background noises. This is accomplished by allowing the listener to strategically place the microphone in close proximity to the sound source to improve the signal-to-noise ratio.

To expect comparable performance from a typical hearing aid in the task of amplifying intelligible sound a distance from its tiny microphone located at the ear of the listener, without concurrently amplifying the masking effects of room noise and reverberation is beyond the state of the art and may always be.

ALDs and Hearing Aids

The selection of a hearing aid is usually made on the basis of many factors including the potential future use of an assistive listening device. This is especially true for those individuals who have severe-to-profound losses or extreme difficulty in discriminating speech. The addition of a telecoil (T-coil) or direct audio input jack to an individual's hearing aid can offer the user greater flexibility and selection of an ALD to supplement the performance of their personal aid in difficult listening situations.

The telecoil was originally designed to pick up the electrical fields generated from a telephone receiver and convert them into a signal that could be directly amplified by the hearing aid. This direct electromagnetic coupling from the telephone to the listener's hearing aid results in an improvement in speech reception over the telephone particularly in areas where high background noise makes telecommunications often impossible. The telecoil can be used alternatively as a means of delivering a high quality signal from an assistive listening device directly to the listener's hearing aid. This permits the user to improve the signal-to-noise ratio in many listening situations by accessing the hearing aid's amplifier directly, eliminating the negative effects of background noise on the perception of the signal.

Incorporating these features into an aid when it is first fitted is not only a convenience to the user but can be an insightful maneuver to assist those individuals with declining auditory function -- a more and more common feature.

From the user's standpoint, there is no fuss over having to obtain and return a special device that would function with the assistive listening system. The hearing aid can be switched from normal to T when required and back again. All extraneous noises are cut out; in fact, in some cases users can hear better than those with normal hearing. A further big advantage is that the volume can be individually adjusted to suit the particular user. From management's point of view, there are no separate hearing devices to be supplied, with their repair, liability and disappearance problems.

Many, but not all, privately-sold hearing-aids incorporate a T-switch. Those worn inside the ear may lack the facility, as there is simply no extra room for a coil and a switch. Some others have an induction coil but no switch, so that both microphone and coil output are heard at the same time. This is less satisfactory than being able to switch the microphone off, but, providing the signal from the ALD is high, it is not too great a drawback.

For those who rely on hearing aids, the application of assistive listening devices provides a tremendous opportunity to improve communications access.

COMMUNICATIONS ACCESS

As society moves into the Communication Age, the need to keep in touch with the events that surround one's life has taken on greater importance. The passive acceptance of the isolation and exclusion that hearing loss had imposed is now being replaced by increased consumer awareness and motivation for self help. Hard-of-hearing individuals are taking a greater interest in their hearing needs, as evidenced by their continuing quest for new technological advancements in hearing assistance. The inclination of the hearing impaired to hide or disguise their hearing loss is slowly disappearing because of the successful application and use of amplification.

Amendments to the National Transportation Act, which became law in July 1988, mean that the National Transportation Agency can require carriers and terminal operators to provide access for travellers with disabilities to equipment, terminals and services. All transportation services under federal jurisdiction will eventually have to be accessible to all persons, including the hearing impaired. This means that the need for hearing assistance systems in terminal waiting areas, restaurants and other facilities is an immediate concern.

2. IDENTIFICATION

The compex problem of alleviating auditory deficiency and its concomitant difficulties cannot be solved by any one instrument. Hearing aids, telecommunications devices for the deaf, telephones with amplification devices, visual messaging systems, and assistive listening devices all have application in improving communications access for individuals with hearing impairments.

The hearing aid has and will continue to serve as an inconspicuous personal speech amplifier for overall listening situations but cannot perform adequately in a very noisy or highly reverberant situation such as a transportation terminal.

Assistive listening devices can play a vital role in determining the success of communication in social situations, personal interactions, educational and vocational achievements and the enhancement of life through spiritual, cultural and recreational experiences. In public venues such as transportation terminals, where communication is vital but background noise and reverberation is onerous, assistive listening devices can facilitate access to information and alleviate feelings of frustration and confusion.

Listening devices which enhance listening are currently divided into four categories: loop, infrared, AM and FM (hard-wired systems are considered obsolete and are not included). The following pages contain information on the commonly available listening devices.

The four categories of assistive listening aids all have one thing in common. They are designed to bring the listener closer to the source of the desired sound, thus reducing undesirable background noise and providing greater intelligibility. The individual's frustration level, in turn, is lessened.

INDUCTION LOOP SYSTEM

The **induction loop system** is made up of a loop of wire placed around a room. This system uses a hearing aid's 'T' (telecoil or telephone) switch. The loop is connected to a special amplifier that receives the signal from the sound source. The loop system is useful for all size groups, small or large, as well as for mini-systems for personal conversation and systems which can be installed in the home to enhance television listening. The biggest advantage of the induction loop system is that the owner of a hearing aid already has half of the system, assuming the aid has a quality T-switch.

The usual mode of reception is a hearing aid equipped with a telecoil (magnetic induction coil). The person with hearing impairments, within the harmless energy field radiated by the loop, turns the hearing aid to the 'T' position (which generally turns off the aid microphone), and hears only what is 'broadcast' by the loop system. Background noise and reverberation is eliminated. A special induction receiver is needed for persons who have no hearing aid or telecoil.

The loop consists of a properly-sized wire or cable placed around the perimeter of the space to be served. The wire is attached to the speaker output of an amplifier fed by microphones or any sound source. The loop system can be portable or permanently installed at floor or ceiling level.

With lower equipment costs but much greater installation labour, the audio induction loop is particularly appropriate for relatively small public rooms (churches, court and council chambers, class and conference rooms). It is the oldest and most popular system in Europe. This is particularly true in transportation settings; in England, for example, most railway stations have been equipped with looped information areas. In addition, these systems have been used in ticket booths throughout England and the Scandinavian countries.

There is no loss of strength as the number of listeners increases. Signal strength (hearing) is excellent and consistent as long as the listener is properly oriented to the loop. Extensive building metal, too small telecoils, specific location within the loop, and head angle can affect the signal. But, depending on the accuracy of the set up as well as the amount of wire used in the loop, it has the ability to accommodate almost any degree of hearing loss. Since the hearing aid telecoil can also be used with a telephone that is 'hearing aid compatible', an induction loop system is compatible with other types of aids.

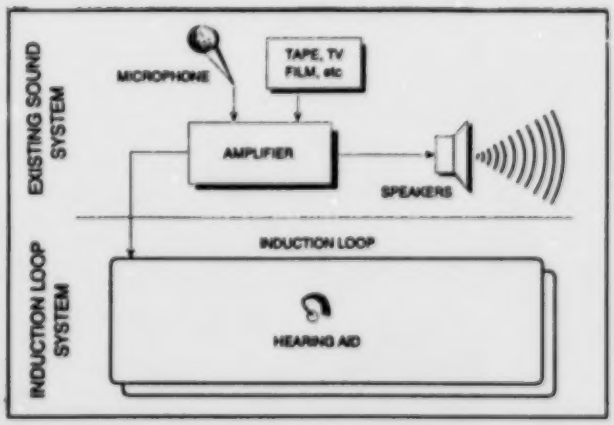


Exhibit 1: **Induction Loop System**

INFRARED SYSTEMS

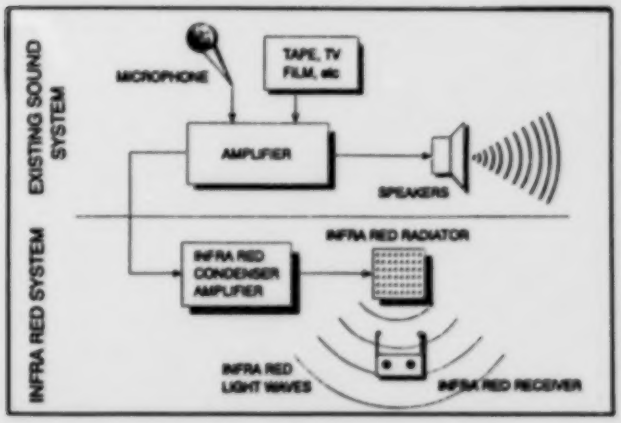
Infrared systems consist of a transmitter and receiver; the medium is invisible light. The transmitter emits a signal consisting of lightwaves which spread throughout the room. The wavelength of the light is outside the range of what humans can see. These light waves carry the message from the sound source and are picked up by receivers worn by the user. A stethoscope earphone can be used, as can the infrared receiver coupled to the user's own hearing aid telephone coil.

The usual receiver is configured somewhat like a stethoscope, with a lightweight unit hanging below the chin from two sound tubes inserted in the ear (similar to airline sound systems). For those with severe hearing loss, the signal can be fed, by neck loop or direct connection, to a hearing aid whose amplifier increases the strength of the sound as required. System installations in public theatres or auditoriums usually have all these available.

A distinct advantage to infrared is that personal receivers, used for watching television at home, are compatible with auditorium systems. Home television systems consist of a small transmitter connected with an audio lead to the television. The stethoscope-type headset receives and converts the encoded signals set out by the transmitter. As home television systems gain in popularity, patrons aware of the public acceptance of infrared transmitters can bring their own receivers, reducing the number of loaners required.

A very high quality signal can be broadcast by invisible infrared light. The same emitter array can transmit up to twelve simultaneous programs for language interpretation or in stereo. Due to the light-based operation, however, infrared signals must be contained within the physical confines of the space in which the transmitters are installed. Broadcasts are by line-of-sight and cannot go through a wall and are therefore contained within the room. For this reason, infrared is the system of choice for many professional theatres and concert halls. Infrared systems are wireless and offer excellent fidelity for radio, television, stereo concerts, lectures and theatre.

Exhibit 2:
Infrared System



Unless expertly installed to take advantage of reflecting surfaces and, possibly, with several emitter panel locations around the room or area, a listener may fall within a 'shadow' from other persons or objects (interrupting the sound). Since the sun emits infrared, daylight and intense incandescent light can interfere with infrared signals.

AM RADIO SYSTEMS

The **AM system** is a radio system consisting of a transmitter and receiver. The transmitter is connected to the existing public address system and the sound is transmitted throughout the area on an AM (amplitude modulation) wavelength. The receiver picks up the signal and sends the sound to the user's ears by way of some type of earphone receiver. The simplest receiver would be a small portable AM radio receiver with a small plastic ear-piece or headphone connected by a short cord and plugged into the radio.

For people with hearing aids with 'T' or 'T/M' switches, it is possible to have special headpieces adapted for use with receivers. Special pocket-size receivers can also be purchased from the manufacturer of the AM system. These receivers, attached to the belt or put in a pocket, direct the sound to the ear via a special attachment that works with the 'T' switch.

For people with hearing aids without a 'T' switch or without hearing aids, small pocket-size receivers deliver sound to the ear via special ear-pieces or headphones connected by a short cord. Patrons could be required to bring their own radios or other receivers.

AM systems have long been used for exhibit narratives in museums and airport access road broadcasts; for example, Parks Canada broadcasts and travel information during Expo 86 in Vancouver. An advantage is that the patron can provide their own AM receiver and tune to the appropriate frequency (sometimes with interference). Seating is not restricted as the signal can be received anywhere in the transmission range. The range, however, is considerably less than an FM radio system (about 20 to 30 meters). The system has the ability to accommodate almost any degree of hearing loss but is dependent on the kind of receiver used. In most auditorium installations, critically tuned loaner receivers are made available. Improperly-adusted receivers can, of course, cause additional hearing loss which should be a major concern. AM transmission is subject to interference and static that normally bothers AM radios (lamp dimmers, ceiling fan controls, thunderstorms, etc.).

Installation is relatively inexpensive but can vary. All that is required is a one to 20 watt, solid state AM transmitter. But few people know how to install the system properly. A qualified sound technician would be required to install an AM radio system to ensure success. Once installed, the transmitter needs little or no maintenance.

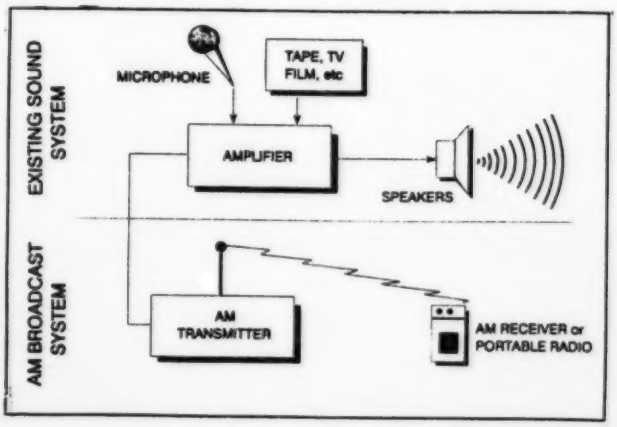


Exhibit 3:
AM Radio System

FM RADIO SYSTEM

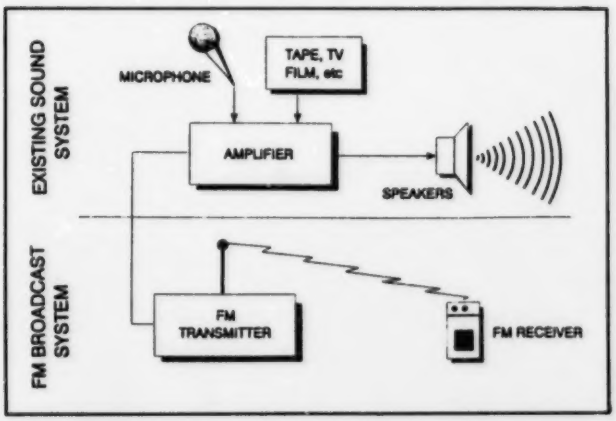
The **FM system** is a radio system consisting of a small transmitter and receiver. The transmitter is connected to the sound source, and a signal is sent to the receiver. The receiver picks up the signal and sends the sound to the user's ears through some type of earphone receiver. The FM system is wireless, offers excellent fidelity for all communication and listening situations and is generally free of interference. The user may also move anywhere within the transmitting range of the system and receive high quality signals from the source.

The speaker uses a microphone transmitter and the user a receiver (both about the size of a cigarette pack) of the same frequency. There are three modes of reception: (1) when no hearing aid is used, sound is delivered from the receiver to any of several types of earphones; (2) with a telecoil-equipped hearing aid, a neck induction loop (small version of a room loop) is plugged into the receiver and the sound picked up by the telecoil (while eliminating surrounding noise, since the aid microphone is turned off); (3) the receiver can be connected by cord to some hearing aids (called direct audio input). Each listener adjusts to the receiver and/or hearing aid to a suitable volume level.

The second variation of this system (neck induction loop) consists of a receiver with a wire loop worn around the neck. The wire acts as an antenna and is connected to the receiver. It transmits the signal to hearing aids which when switched to the telephone coil or 'T' position make the hearing aids sensitive to the magnetic field generated from the wire.

FM systems are generally recommended over AM because the sound quality and reduced noise levels are superior. There is no interference from commercial stations because the Department of Communications has set aside a band of frequencies -- 32 narrowband channels -- specifically for assistive hearing broadcasts. If several channels are in simultaneous use (schools, courthouses, multi-language meetings), the narrowband channels are needed. In an auditorium setting where only one program is to be broadcast, the wideband channels are advantageous. The wideband systems permit a greater dynamic range, resulting in an improved signal-to-noise ratio.

Exhibit 4:
FM Radio System



Since an FM signal goes through walls, the signal can be received anywhere within its range of 30-90 m with excellent fidelity. Of course, this has the potential of interference with other programs being broadcast on the same frequency. This can be corrected with a telescoping antenna.

3. ASSESSMENT

Four types of assistive listening systems are being used in North America: audio induction loops, infrared wireless and FM or AM radio systems. Previous research has shown no significant difference between them in the speech discrimination provided to listeners with hearing impairments in carefully controlled situations. The choice of which system to install in a particular place is determined by practical considerations such as cost, sound interference, availability of receivers, and the users' propensity for self-identification.

The parallel use of these different systems -- one here, another there -- discourages the personal ownership of receivers, and a location such as a church or a theatre offering hearing assistance must therefore provide not only the transmission, but matching receivers as well. The provision and maintenance of these receivers -- the chores of cleaning them, and keeping their batteries charged -- represent a major burden, and this discourages the provision of hearing assistance. In public places such as transportation terminals, users may also be disinclined to wear special receivers since the receivers then identify the user as a person with a disability.

There are several types of assistive devices from which to choose: audio induction loops, infrared systems, and FM or AM radio broadcast systems. How then are recommendations to be made? What criteria should be used in the selection of assistive devices? Concerns of the users are important, as are the capabilities and limitations of the responsible authority. It would be of little value to install an expensive, high-quality system if the users are hesitant to use the special receivers that may be required. The following criteria are considered and discussed: (1) sound transmission, (2) sound reception, (3) user requirements, and (4) system requirements.

Exhibit 5: **Comparison of Assistive Listening Systems**

	Audio Loop	Infrared	AM Radio	FM Radio
DESCRIPTION	Sound transmitted by induction field from wire loop around room. Listen with hearing aid 'T' switch or special receiver.	Sound transmitted by invisible light rays emitted from high front of room. Listen with special receiver.	Sound transmitted by AM radio to either personal radio or special receivers. Listen with earphone.	Sound transmitted by FM radio to special receivers on special frequencies. Listen with earphone or neck loop.
COMPONENTS	Amplifier, microphones 50-200' wire loop Receivers (half as many required)	Amplifier, mics Emitter panel(s) Receivers & charger	Amplifier, mics AM transmitter 10' antenna Receivers & charger	Amplifier, mics FM transmitter Sometimes antenna Receivers & charger
INSTALLATION	8-12 hours Arrange/attach loop	1-2 hours Panel mounting	3-4 hours Audio skills	1-2 hours Audio skills
COVERAGE	50-500 sq meters	500 sq meters per panel	750-1,500 sq meters	50-75,000 sq meters
SEATING	Within looped area	'Shadow' potential	Anywhere	Anywhere
SECURITY	Privacy for short distance but some sound spillover	Privacy ensured within room or walled area	Passes walls	Passes walls
PORTABILITY	Many portable	Requires tripod(s)	Restricted	Some very portable
RECEIVERS	Hearing aid telecoil or pocket w/ecc	Neck suspension with various accessories, self-identification	Pocket with various ear accessories, self-identification	Pocket with various ear accessories, self-identification
POWER	All hearing loss	All hearing loss if coupled with aid	All hearing loss if coupled with aid	All hearing loss if coupled with aid
EXPANSION	Enlarge loop	Add panels, receivers	Add receivers	Add receivers
APPROX COST Transmitter Receivers Typical System	 $350-1000 $0-75 $1000	 $1300/panel $100-300 $2000	 $350-1000 $10-35 $1000	 $350-2000 $50-300 $1500
ADVANTAGES	Receiver not needed if aid has 'T' switch. Relatively inexpensive. Easy to 'tie' into existing sound systems. Privacy or room loops.	Good sound. Home receivers compatible. Remains inside the room, ensuring privacy. Can be used with remote or wire microphone.	Less cost than FM. Portable radios are readily available.	Excellent sound quality. Readily portable and easy to install and operate. Freedom of movement is ensured. Large areas/one-to-one.
LIMITATIONS	Sound may not be uniform due to variations. More labour if large. Repairs can be costly if the wire is hidden. Interference can occur.	Bright light interferes. Special headset receivers are required. Light rays do not penetrate walls. Receiver must be 'trained' on the transmitter.	Poor sound, static. Special adjustments must be made to be used with a hearing aid.	More expensive than AM and loop, especially with environmental mic. Privacy restricted as FM waves go through walls.

SOUND TRANSMISSION

With an audio induction system, the sound is transmitted via the existing PA system through a length (loop) of wire strategically placed around a seating area. The loop wire can be hidden in the wall, floor or ceiling. It is relatively easy to install but few people install the system properly. Qualified technicians can certainly assist. For a relatively large area, the power demand of the amplifier can be quite high. Since the loop system can be designed to service small areas, it is compatible with the existing 'zoned' public address system at boarding gates in a transportation terminal and would be suitable in small areas such as a check-in counter. It would not work, however, for announcements throughout the whole terminal.

With an infrared system, sound is transmitted via microphone and amplifier or through the existing PA system to one or a series of special emitters which sends invisible infrared light into the room. Ease of installation is dependent on the size of the room in which the installation is being completed. Like the audio induction loop system, the infrared transmitter's power demand is high, and it can therefore be an expensive way to service a large area. Mobile battery-powered infrared transmitters have been made, but the system's high power demand allows only a short battery life. Since the infrared light beams are affected by high intensity light, such as fluorescent lighting which is normally found in transportation terminals, the system is not very compatible with the existing operation.

Both the AM and FM broadcast system require the use of a special transmitter and antenna. The sound is transmitted through the existing PA system throughout the room on either an AM or FM wavelength. Since AM transmissions are highly susceptible to interference from other electronic control systems, problems would probably exist in a busy transportation terminal.

The FM system is a popular solution to accessible messaging in many public venues, such as airports and other transportation terminals. For 'zoned' public address announcements, different frequencies can be used; unfortunately, this would require the user to constantly change channels on their receiver. Personalized FM systems are also available that could be used at ticket counters or information booths. The difficulty would be in ensuring privacy for the individuals carrying out a conversation.

Within the Greater Vancouver Area, no transportation terminals are equipped but a number of theatres, churches and classrooms have assistive listening devices. Compatibility with these systems is also a concern but there does not seem to be any one system which is favoured. Thirteen audio induction loop systems, nineteen infrared systems and two FM systems have been noted. Some of the more familiar systems include: loop systems in two Vancouver cinemas, infrared systems at both the Orpheum and the Queen Elizabeth theatres, a loop system at the Vancouver Community College, an infrared system at Simon Fraser University and an FM system at the University of British Columbia.

SOUND RECEPTION

Overall, if the audio induction loop system is properly installed, the sound quality is quite good. The reception, however, is often subject to interference from the alternating currents in nearby electrical wiring. This interference is heard as a continual hum. The International Electrotechnical Commission promulgates a standard (IEC Standard 118-4) for audio induction loop systems, which specifies the frequency response, and the strength of the signal that should be maintained across the listening area. This standard warns that hum interference can prevent a loop system from being used in certain locations. IEC Standard 118-4 also warns that a loop system may interfere with the operation of sensitive electronic equipment nearby.

Another disadvantage of the audio induction loop system is that the level of reception varies with the strength of the signal, which may not remain constant across the listening area. The volume control on the hearing aid may therefore need to be set according to where the listener is seated relative to the loop. This is not too much of a problem for example, in church, where there is time to adjust the volume control without missing more than a few moments of the service. If audio induction loops were to be used to help travellers with hearing impairments to understand announcements in places like airports, however, careful consideration of design guidelines would be necessary. Otherwise, the users' may not be able to adjust their volume controls until an announcement had commenced, and a brief announcement might well be completed before they had found a satisfactory volume setting.

Infrared wireless systems perform excellently in certain places, such as theatres and churches. Its chief advantage is that its signals don't penetrate ordinary building materials, and that there is therefore no spill-over from one room to another. This is however, also its chief disadvantage for large public areas such as transportation terminals. Infrared systems are especially susceptible to interference from the infrared components of some forms of strong lighting. Excessive sunlight, fluorescent lighting and people passing between the transmitter and receiver can interrupt the signal. If only portions of a brief announcement were heard, it could be very annoying to the user. Due to these limitations, infrared systems are not considered practical for transportation terminals.

One of the main advantages of the frequency modulation, or FM system, is the high quality of the signal. The receiver's output remains at a constant level, regardless of the strength of the incoming signal, and regardless of the distance from the transmitter. When the signal becomes too weak, the reception just drops out. The constant reception level provided by FM will be particularly valuable if wireless is introduced to help travellers with hearing impairments understand announcements, since it will allow them to leave their receivers' volume controls preset at the correct level. FM system minimizes interference, regardless of whether it originates from electrical equipment, or from a competing transmission.

USER REQUIREMENTS

The great advantage of the audio induction loop is that many hearing aids are already equipped with a little coil to receive its signals. The hearing aid actually functions as an elementary wireless receiver. The performance of this wireless system depends upon a very strong signal being transmitted, and the audio induction loop system is therefore most suited to small areas, because its power demand becomes too high for a large area. A very powerful and expensive audio amplifier is then required to drive sufficient current around the loop. For people with hearing aids without a T-switch or without hearing aids, special portable receivers such as hand held wireless wands or miniature battery operated amplifiers or headsets would have to be made available.

For both the infrared system and the FM system, for people with hearing aids with a T-switch, special pocket size receivers with a neck loop or a silhouette placed between the hearing aid and the head or direct audio input into the hearing aid are available. For the AM system, it is possible to have special headpieces adapted for use with receivers. Special pocket size receivers can be purchased which are attached to the belt or put in a pocket. They direct the sound to the ear via a special attachment that works with the T-switch.

For people with hearing aids without a T-switch or without hearing aids, special headset receivers are available for the infrared system and special pocket size receivers with light-weight headsets (stethoscope attachments or chin tubes) for the ears are available for the FM system. For the AM system pocket-size receivers deliver sound to the ear via special ear-pieces or headphones connected by a short cord. Small plastic ear-pieces or headphones can be bought by the user and plugged into a portable radio for AM installations. Patrons could be required to bring their own radios.

The parallel use of these different systems discourages the personal ownership of receivers, and sites offering hearing assistance must therefore provide not only the transmitters, but matching receivers as well. The provision and maintenance of these receivers represents a major burden, especially when it may be coupled with liability considerations imposed by the fact that improperly-tuned receivers may in fact aggravate hearing loss for some individuals.

In public places such as transportation terminals, users may also be disinclined to wear special receivers that would, in essence, identify the user as a person with a disability. Many individuals with disabilities naturally do not wish to identify themselves as such since it often affects the way that others deal with them -- they wish to be treated the same as anybody else. The problem of self-identification is difficult.

It would appear that from both the users' and operators' perspective, that the best option is to rely on the user to be responsible for obtaining the proper receivers. And, as a result, the audio induction loop transmitter coupled with the user's T-switch-equipped hearing aid appears most feasible and practical.

SYSTEM REQUIREMENTS

Installation Requirements. For a personalized FM system, the personal transmitter and one or more receivers is all that is required. For the large-area system, the audio control would connect to the existing PA system and all that would be required would be the necessary cables, antennas and receivers. For the infrared system, infrared light emitters, individually or in series, connected to a power supply and the PA system would be required, as well as special receivers. For the audio induction loop, lengths of induction loop wire would have to be connected to the PA system or systems.

Seating Requirements. For people who use the loop, seating is restricted to the area circumscribed by the wire loop. Weak or dead spots can occur. There are no seating restrictions inside the room that contains the infrared system. The infrared light rays do not penetrate walls. For the wireless systems, there are no seating restrictions and freedom to move throughout the area is provided.

System Application. The FM system is a popular system for all public address announcements, including emergency warnings. This would not, however, meet the requirements at the boarding gates or the check-in counters. In these areas, if personl FM systems are used, there would be the opportunity for others to overhear private conversations. With the FM system, announcements could not be directed, for example, to individual waiting areas. The audio induction loop system would have a broader and more flexible application, covering both large areas and intimate converstational concerns. Pocket receivers could be provided to those without appropriate hearing aids or to others, including visually-impaired travellers.

System Upkeep/Care. For all systems, the transmission system needs little or no maintenance. Portable receivers, however, need to be distributed, collected and wiped after each use. Batteries for receivers are required and these can be rechargeable. With any system, the distibution and collection of receivers represents the major investment and liability. As much reliance as possible has to be made on the users themselves to be responsible for obtaining and using hearing aids that are appropriately equipped to receive signals from assistive listening devices. Of course, this may not occur until assistive listening devices are universally installed in public buildings.

System Compatibility. As mentioned, compatibility with other systems is a concern; but, when looking at all applications, there does not seem to be any one system which is favoured. Different sites (theatres, churches and classrooms) may all have different types of assistive listening devices. Perhaps of greater concern would be compatibility with other devices within the transportation terminal itself. Hearing-aids with T-switches are compatible with audio induction loops since the T-coil is designed to respond to the magnetic field in the telephone receiver. The other assistive listening systems would require special receivers and/or connective devices. Loop systems are therefore compatible with most public pay telephones within the transportation terminal.

System Cost. If only one system was to be used for all public address announcements, the FM system would probably be the most inexpensive. Next to the FM system, the audio induction loop system would be the least expensive -- especially if coupled with the fact that special receivers may not have to be provided. The design and implementation of the system could be incremental with expenses occurred only as the need was demonstrated.

POTENTIAL SYSTEMS

The audio induction loop and infrared wireless systems are normally used for applications like hearing assistance that do not demand a long transmission range. When wireless communication is required to span greater distances, radio is invariably used, because it is the most energy-efficient form of wireless transmission. FM systems are therefore most suitable for public address announcements throughout the terminal. When the quality of sound is the major concern, such as in a concert hall (Queen Elizabeth Theatre or the Orpheum in Vancouver), the infrared system is the system of choice. For all systems, pocket receivers can be provided for those without their own appropriate hearing aid.

In a transportation terminal, when the requirements are for public address announcements throughout the terminal and individual waiting areas as well as individual one-to-one correspondence at ticket counters and information booths, it would appear that only the audio induction loop system would meet all the requirements. Nonetheless, because of the advantages of FM radio, both the FM radio system and the audio induction loop system were chosen for further investigation and testing in a transportation terminal setting.

4. APPLICATION

During all phases of transportation facility use -- planning, moving through the terminal and on board -- there is a constant need for relevant, easy to understand information -- information about orientation within the facility, wayfinding around the facility and procedures to follow to complete a trip. This information is an essential part of travelling and must be conveyed in a method that is easily understood by all transportation facility users.

Travellers with hearing impairments are at a particular disadvantage in transportation facilities. These travellers rely heavily on information cues to guide them through a transportation facility. In many instances, information is conveyed only one way, either visually or orally, but rarely both. And in some instances the information conveyed is not clear. Previous reports have outlined the difficulties experienced by travellers with sensory disabilities (*12*,*13*). These studies showed that travellers who are, in particular, hearing impaired or hard of hearing have specific problems related to information retrieval.

Difficulties especially arise when retrieving auditory information from airport personnel and from public address announcements. Assistive listening devices can alleviate these difficulties and they have the potential to improve information retrieval and to facilitate travel for individuals with hearing impairments.

The application of assistive listening devices to the design a transportation system which will facilitate travel for individuals who are hard of hearing requires an understanding of the needs and capabilities of these individuals as they relate to the tasks which will be carried out in the transportation facility. An analysis of the tasks and an appreciation of the needs is presented in the following chapter.

BASIS FOR UNDERSTANDING

Methodology for Understanding

To assess the possible applications of new technologies (loop systems) to assist the traveller with hearing impairments, a four-stage investigation was carried out at the Vancouver International Airport.

First, a review of the communication systems available in the Vancouver airport was conducted. Information was gathered through discussions with airport officials, a review of previous literature and several airport walk-throughs. Note was taken of the location of the information system, the content and the form of presentation (visual/oral) of the information.

Second, a task analysis of airport terminal use was undertaken. The information required to complete each task was noted. This analysis reveals stages of terminal use in which vital information is conveyed orally without visual back-up. These stages could benefit from assistive listening devices.

Third, to gain an appreciation of the needs of travellers who may be hard of hearing, a focus group session was held. Four hard-of-hearing travellers took part in discussions about their travel experiences, the use of loop systems and suggestions for the application of loop systems within an airport terminal.

Last, a technical evaluation of both audio induction loop and FM radio systems was performed in the Vancouver airport with qualified technicians and ALD users. The evaluations were conducted at locations which the task analysis and focus group sessions indicated might benefit from the use of an ALD system.

Understanding the Users

In this report transportation facility users will include the travelling public, as well as the attendant traveller who may accompany or pick up a traveller within the facility. The information needs of these groups vary based on personal, social and economic characteristics as well as on their involvement with the transportation system. The different types of travellers can be categorized as:

- *Regular travellers* - who may use a transportation service on a regular basis. Since they are very familiar with the service, their information requirements may be assumed to be minimal.
- *Attendant travellers* - who may drop off or pick up another passenger at the transportation terminal.
- *Occasional travellers* - who use transportation for a specific trip, are not very familiar with the service and, therefore, have a high information requirement. Occasional travellers include travellers who are unacquainted with the service and facilities, those who have additional communication difficulties due to language, and those who have certain functional limitations which may or may not relate to communication difficulties.

EXISTING SYSTEMS/DEFICIENCIES

Review of Information/Communication Devices

A review of information/communication systems in the Vancouver airport was conducted. These systems included orientation, wayfinding, procedural and other communication systems such as maps, signs, human contact and PA systems. Two notable systems which were included are *Communicaid*, an integrated communication system for individuals with 'communication impairments', including speech, language, or hearing difficulties; and *Translaid*, a portable device with similar capabilities. Communicaid was designed to provide much-needed information on arrivals and departures, as well as on the location of key terminal services. Translaid presents a touch-screen and speaker to both the traveller and agent to facilitate communication.

The maps and tables on the following pages (Exhibits 6 and 7) provide an outline of the type of information or communication system available in the airport and the form in which the information is conveyed. The type of information is coded by number on the maps and tables in order to show where the information systems are located in the airport.

Task Analysis of Terminal Use

In order to determine whether these information systems are adequate to assist the traveller with hearing impairments through an airport terminal, it was necessary to conduct a task analysis of the travel process, given that the use of transportation services and facilities necessitates the performance of specific tasks, including:

- Travelling to and from the air terminal;
- Moving around the departure/arrival terminal;
- Using timetables, video screens, hearing announcements, etc;
- Understanding the operation of the transportation system (i.e, understanding routes, schedules, fare structures, etc);
- Communicating with transportation system personnel to purchase tickets and check baggage;
- Using the facilities at the terminal, including the restroom facilities, restaurants, and so on; and
- Boarding, disembarking and riding.

This analysis of the travel process was undertaken for two types of terminal user: (1) a traveller, and (2) an attendant traveller (who accompanies the traveller but does not travel themselves). The task analysis was conducted after interviews with hard-of-hearing travellers and several airport walk-throughs.

The results of the task analysis follows the review of information devices on the following pages (see Exhibits 8 and 9) and shows where each of the information devices are used within the travel process.

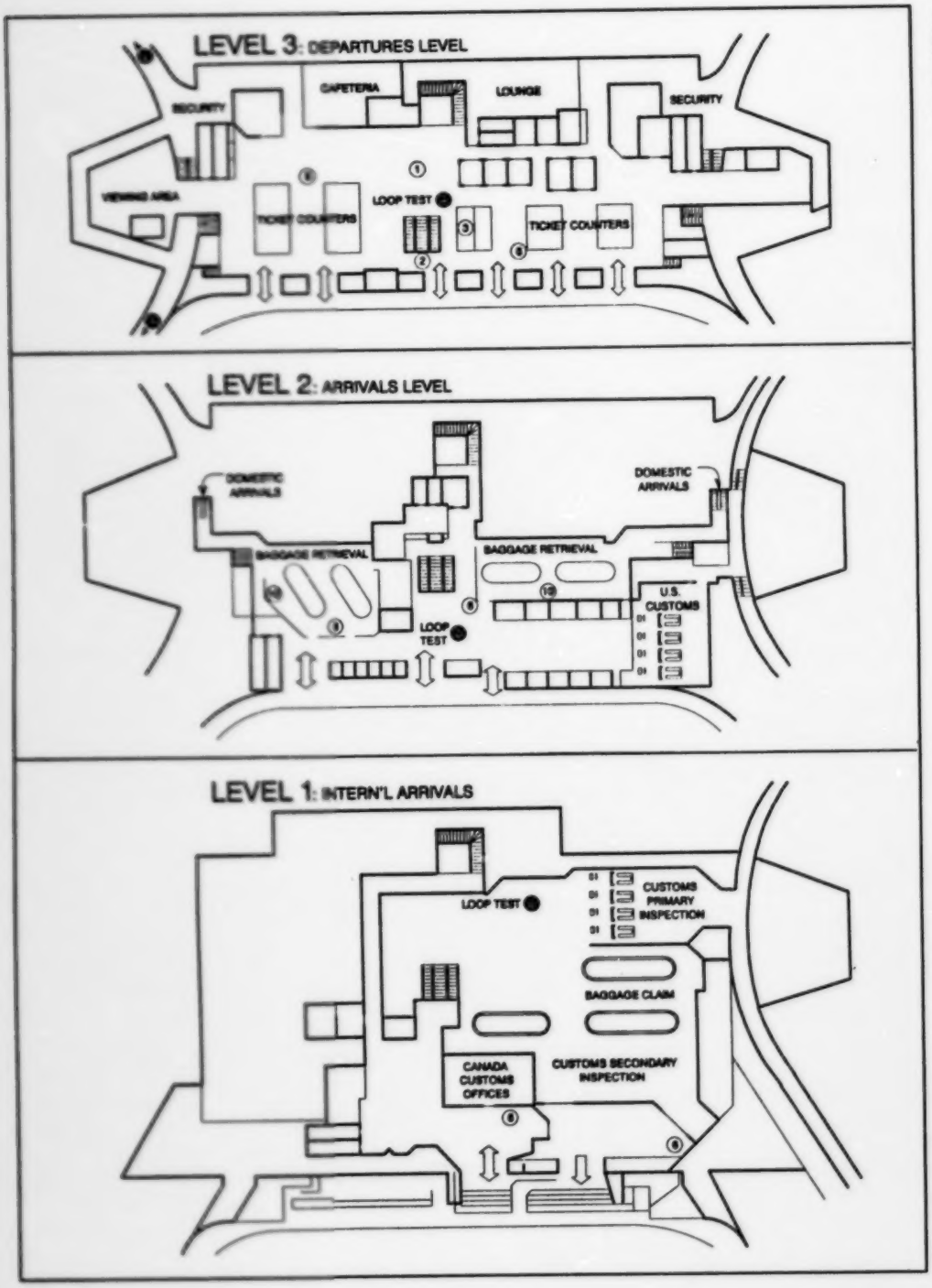


Exhibit 6:
Map of the Vancouver International Airport

Exhibit 7: **Information Systems at the Airport**

Category	Type of Information	Content	Form
Orientation			
①	Map of Terminal	Instruction for Direction/Location General Information	Visual
②	Communicaid*	Instructions for Direction/Location	Visual, Auditory
③	Information Counter	Instructions for Direction/Location, General Information	Human-Auditory (some Visual)
Wayfinding			
④	Signage: pictograms, symbols	Direction/Location	Visual
Procedural			
⑤	Clocks	Time	Visual
⑥	Departure/Arrival Screen	Schedule	Visual
⑦	Departure/Arrival Announcements	Changes/Time/Delays	Auditory
⑧	Special Services	Instructions & Procedures	Human-Auditory (some visual)
⑨	Signage: Symbols	Emergency Baggage Pick-up Special Instructions	Visual
⑩	Hotel Reservation Board	Hotel Prices Hotel Phone Numbers	Visual (some Auditory)
⑪	Human Contact	Ticket Counter, Check-in, Security & Boarding Gate, Boarding Procedures	Human-Auditory (some Visual)
⑫	P.A. System	Special Announcements, Paging, Flight Changes, Boarding and Emergencies	Auditory
Communication			
⑬	Translaid*	Various	Visual
⑭	TDD	Various	Visual
⑮	Telephone	Various	Auditory

NOTE:** ***Communicaid **is an integrated communication system for individuals with speech, language or hearing difficulties;** ***Translaid*** **is a portable device with similar capabilities (see page 21).**

No	Task	Process	Source	Form
1.0	ENTER AIRPORT			
2.0	GAIN FAMILIARIZATION WITH THE AIRPORT			
2.1	Locate General Information Counter	P, M	Human Contact	V
	2.1.1 Obtain Specific Information Required	C, P, M	Info Counter	A/v
2.2	Locate Orientation Information on Airport	M, P	Signage	V
	2.2.1 Obtain Specific Information Required	C, P, M	Map	V
			Communicaid	A/V
2.3	Locate Ticket Purchase/Check-In Counters	P, M	Signage	V
3.0	PURCHASE TICKET			
3.1	Locate Correct Line-up	P, M	Signage	V
3.2	Stand in Line-up	M		
3.3	Determine Flight			
	3.3.1 Choose Location	C, P	Human Contact	A/v
	3.3.2 Choose Flight Time	C, P	Human Contact	A/v
3.4	Pay for Ticket	C, M	Human Contact	A/v
3.5	Obtain Ticket	C, M	Human Contact	A/v
4.0	CHECK-IN			
4.1	Locate Correct Line-up	M, P	Signage	V
4.2	Stand in Line-up	M		
4.3	Present Ticket	M	Human Contact	A/v
4.4	Present Identification	M	Human Contact	A/v
4.5	Make Seat Selection			
	4.5.1 Communicate Seat Preferences	C, P	Human Contact	A/v
	4.5.2 Verify Choices	C, P	Human Contact	A/v
4.6	Check and Deposit Baggage			
	4.6.1 Locate Baggage	P	Human Contact	A/v
	4.6.2 Put Baggage on Scale	M	Human Contact	A/v
	4.6.3 Pay Excess Baggage	C, M	Human Contact	A/v
	4.6.4 Communicate Pick-up Time/Directions	C, P, M	Human Contact	A/v
	4.6.5 Receive Baggage Tags	M	Human Contact	A/v
4.7	Obtain Boarding Pass			
	4.7.1 Verify Gate Number	C, P	Human Contact	A/v
	4.7.2 Verify Boarding Time	C, P	Human Contact	A/v
5.0	WAIT FOR FLIGHT			
5.1	Locate Orientation Information			
	5.1.1 Locate Washrooms	C, P	Map, Signage	V
	5.1.2 Locate Duty Free/Shopping	C, P	Map, Signage	V
	5.1.3 Locate Services	C, P	Map, Signage	V
	5.1.4 Locate Waiting Areas	C, P	Map, Signage	V
	5.1.5 Locate Telephones/TDD	C, P	Map, Signage	V
5.2	Verify Wayfinding Information	C, P	Signage	V
5.3	Proceed to Desired Area	M		
5.4	Verify Flight Itinerary			
	5.4.1 Verify Time	C, P	Clock	V
	5.4.2 Verify Gate Number	C, P	Dep/Arr Screen	V
	5.4.3 Verify Departure Time	C, P	Dep/Arr Screen	V

Exhibit 8:
Task Analysis for Travelling in Airports

No	Task	Process	Source	Form
6.0	PROCEED TO GATE			
6.1	Verify Flight Itinerary			
	6.1.1 Verify Time	C, P	Clock	V
	6.1.2 Verify Gate Number	C, P	Dep/Arr Screen	V
	6.1.3 Verify Departure Time	C, P	Dep/Arr Screen	V
6.2	Locate Direction for Gate	C, P	Signage	V
6.3	Proceed Through Security			
	6.3.1 Locate Security	C, P, M		V
	6.3.2 Present Boarding Pass	M	Human Contact	
	6.3.3 Remove Metal Objects	P, M	Human Contact	A/v
	Remove Hearing Aid	P, M	Human Contact	A/v
	6.3.4 Pass Through Security	P, M	Human Contact	A/v
	6.3.5 Pick-up Personal Items	P, M	Human Contact	A/v
6.4	Locate Direction for Gate	C, P	Signage	V
6.5	Find Gate			
	6.5.1 Verify Gate Number	C, P	Signage	V
	6.5.2 Verify Flight Destination	C, P	Signage	V
	6.5.3 Verify Flight Time	C, P	Dep/Arr//PA	V//a
	6.5.4 Verify Time	C, P	Dep/Arr//PA	V//a
7.0	WAIT FOR BOARDING			
7.1	Find Seat	P, M		V
7.2	Communicate with Boarding Gate Attendant	P, C	Human Contact	A
7.3	Await Boarding Announcement	P	PA System	A
7.4	Locate Services			
	7.4.1 Find Washrooms, Drinking Fountain	P, C	Signage	V
	7.4.2 Find Snack Bar	P, C	Signage	V
8.0	BOARD	P, M		
9.0	DE-PLANE			
10.0	CUSTOMS			
10.1	Locate Customs	P, C	Signage	V
10.2	Locate Correct Line	P, C	Signage	V
10.3	Stand In Line	M		
10.4	Present Documents	P, M, C	Human Contact	A/v
11.0	RETRIEVE BAGGAGE			
11.1	Locate Wayfinding Clues	C, P	Signage	V
11.2	Listen for Announcements	P	PA System	A
11.3	Locate Appropriate Baggage Carrousal	P	Signage//PA	V//A
11.4	Pick Up Baggage	M		
12.0	ARRANGE HOTEL			
12.1	Choose Hotel	P, C	Reservation Board	V
12.2	Phone Hotel	C, M, P	Reservation Board	A
13.0	LEAVE AIRPORT			
13.1	Get Ground Transportation			
	13.1.1 Locate Departure Areas	P, C	Signage	V
	13.1.2 Determine Schedules	P, C	Human Contact	A/v
13.2	Leave Airport	P, M	Signage	V

Notes: *M denotes Motor* *P denotes Perceptual* *C denotes Cognitive*
V denotes Visual *A denotes Auditory*
lowercase letters denote sometimes

No	Task	Process	Source	Form
1.0	ENTER AIRPORT			
2.0	GAIN FAMILIARIZATION WITH THE AIRPORT			
2.1	Locate General Information Counter	P, C	Signage	V
	2.1.1 Obtain Specific Information Required	C, P, M	Human Contact	A/v
2.2	Locate Orientation Information on Airport	P, C	Signage	V
	2.2.1 Obtain Specific Information Required	C, P, M	Map	V
3.0	VERIFY FLIGHT ARRIVAL			
3.1	Locate Departure/Arrival Information Screens	P, C	Signage	V
	3.1.1 Verify Flight Time	P, C	Dep/Arr Screen/PA	V/A
	3.1.2 Verify Point of Entry	P, C	Dep/Arr Screen/PA	V/A
4.0	WAIT FOR FLIGHT			
4.1	Locate Orientation Information			
	4.1.1 Locate Washrooms	C, P	Map, Signage	V
	4.1.2 Locate Shopping	C, P	Map, Signage	V
	4.1.3 Locate Services	C, P	Map, Signage	V
	4.1.4 Locate Waiting Areas	C, P	Map, Signage	V
	4.1.5 Locate Telephones/TDD	C, P	Map, Signage	V
4.2	Verify Wayfinding Information	C, P	Signage	V
4.3	Proceed to Desired Area	M	Signage	V
5.0	MEET PARTY			

Notes: *M denotes Motor* *P denotes Perceptual* *C denotes Cognitive*
V denotes Visual *A denotes Auditory*
lowercase letters denote sometimes

Exhibit 9:
Task Analysis for Attending Travellers in Airports

The task analysis shows explicitly where information gaps occur for the traveller with hearing impairments. The gaps are most apparent where information is presented orally without any visual backup. In most cases, oral information is garbled, spoken too softly or quickly, or is buried in high levels of background noise, making it difficult for the hard-of-hearing listener to understand.

The task analysis shows that information is only presented in an oral mode:
- at the general airport information counter,
- when listening to announcements,
- at check-in and when purchasing a ticket,
- at security and going through passenger security,
- at the boarding gates when getting ready to board,
- when passing through customs upon arrival,
- phoning to make hotel/accommodation arrangements, and
- finding out about ground transportation services and schedules.

In addition, oral information is presented to the attendant traveller when waiting to hear about flight changes.

In each of these instances, information which is currently presented orally might not be heard at all or might be completely misunderstood by the hard-of-hearing traveller -- leading to frustration, confusion and possibly even unnecessary mishaps such as going to the wrong gate or even boarding the wrong plane.

Other research reports have shown that although information is presented visually, it is often not perceived correctly by all travellers and is therefore inadequate. One recent report (*16*) found that "signage in airports is the weakest link in the airport/passenger communication chain". Signage in general was found to be obscured by glare and presented a mixture of symbols that were difficult to understand. In many cases, there were too many signs for the traveller to be able to obtain any useful information. Another report (*17*) found that emergency signage in the Vancouver airport was not easily understood by any of the hearing impaired travellers questioned. It also found that the arrival and departure screens were difficult to understand. Letters were generally too close together, information was presented in abbreviations and the 24-hour clock was confusing.

When signage is incomprehensible or confusing, facility users have to rely on oral information from human contacts (agents or other travellers) in order to gain information. This presents difficulties for the hard-of-hearing traveller. It is imperative that signage be improved to a level where it is comprehensible for all travellers. By providing good signage the need for other supporting information systems is lessened. Some parts of the travel process which cause difficulties for hearing-impaired travellers can be improved solely by signage which is better designed, whereas other parts of the travel process require support from information presented both visually and orally to ensure that the facility user has a smooth trip through the terminal.

THE USERS' EXPERIENCE

A focus group discussion session was conducted with a group of hard-of-hearing travellers in order to investigate further which parts of the travel process might require a loop system from the users' (or *real-world*) perspective.

In the focus group sessions, four hearing-impaired travellers were interviewed in a group session for 2½ hours. Two females and two males attended, each of whom have had extensive experience with loop systems. Ages ranged from 28 to 72 years of age. All of the participants were experienced travellers with a range of frequency of travel from one to six times per year, both locally or internationally. All had experienced the difficulties of travelling through an airport by themselves at some point. The degree of hearing loss ranged from some tone loss to severe loss in both ears and all had T-switches on their hearing aids. The meeting was conducted using a loop system.

Participants were asked to share their travelling experiences, their concerns about travelling through an airport terminal, the critical areas for information within the airport, their feelings about using different assistive listening devices in different situations, and their thoughts on where in the airport the application of a loop system would be most beneficial. The results of these discussions are summarized in the following paragraphs.

Experiences when Travelling

The discussions made it clear that travellers who are hard-of-hearing do experience difficulties when travelling through airport terminals. A representative comment from a frequent traveller was *"I have travelled all over the world and it's been getting more and more difficult to hear what everyone's saying at any airport. It's the same problem all over the world. Difficulty understanding isn't just localized in Canada. I have my wife along. She's a hearing person and she's indispensable"*.

Some travellers specifically complained of not being able to understand the public address announcements, especially when made by someone with a heavy accent. Others complained of misunderstandings at ticket counters. One traveller who travels with a hearing guide dog and always makes prior arrangements with the airline, expressed difficulties convincing agents at the airport that she is allowed to take her dog on board. Most of the group said that they experience considerable stress when they travel because they realize they may be missing important information about flight changes, gate changes or delays. They tend to rely on visual cues from watching other passengers (anticipating that the other passengers are going in the right direction). One traveller suggested that a hard-of-hearing traveller has to be very aggressive to make sure that they get the needed information. Many hard-of-hearing travellers don't relax until they are on sitting down on-board the flight (unfortunately this is the time when they are most susceptible to serious problems and even dangerous situations (*16*); but that is a concern for other studies).

It is evident from the discussions that negotiation through a terminal is still a difficult process for passengers who are hard of hearing.

Concerns when Travelling through a Terminal

Buying a Ticket and Checking In was one of the first topics of discussion for the group participants. The biggest concern expressed was difficulties in communicating with the ticket agents. One traveller complained that agents tend to look down when they are speaking so that it is very difficult to lip-read. *"When they talk at their shoelaces, it's no good."* Other travellers complained that even if they asked the ticket agents to raise their voices, they would only do so for about 20 seconds; thereafter, it would be impossible to hear them again. Some travellers thought that these problems could be overcome through better personnel training. Furthermore, unlike some other disabilities, there is some reticence at self-identification as a hard-of-hearing individual. The association of 'mental slowness' with hearing impairments is still present in our society.

Orientation and Wayfinding weren't major concerns for the traveller who is hard of hearing, although several participants expressed the concern that Canadian airports were much more difficult to negotiate than some European ones. Hard-of-hearing travellers rely heavily on maps, signs and other wayfinding cues. If

these cues are inadequate, their travel through the terminal is much more difficult. One traveller suggested that Canadian airports should be modelled after some of the European ones: *"... for example in Amsterdam airport you have the colour coding system. All the washrooms are yellow, the baggage areas green, etc. All international airports should be colour coded the same way."* Another traveller suggested airports should have a information map in which the legend has buttons that light up the indicated location on the map.

Changes in Flight Schedules was a big concern for many of the participants. Most changes to flight schedules are announced over the public address system at the last minute. Most travellers with hearing impairments are unable to understand the public address announcements. The situation is aggravated when the flight departure display screens are not changed immediately, which is often the case. This causes extensive problems for the hard-of-hearing traveller. There are numerous stories of travellers missing their flight or getting on the wrong flight because they didn't hear the flight schedule change. *"... travelling in Europe the airline turned around and changed the gate number, but not on the screen. Fortunately, my wife has perfect hearing because if she didn't have I would have missed my flight. I was still watching the screen which didn't show the change".* Verbal information should always be supported by visual information. One participant suggested putting in a phone for T-switches (or a sound deadened booth) where you press a button to receive the latest schedule for the airline of your choice. A waiting area with a loop system might also be useful in this situation.

Terminal Services and Facilities for travellers who are hard of hearing was another concern expressed. All focus group participants were dissatisfied with the number and location of T-switch phones. *"In Toronto, very few of the pay phones work and the ones that do are stuck under a great big light which causes a great big power hum. The Vancouver airport has the same problem".* It was also mentioned that no T-switch phones are available that accept credit cards instead of coin. Signage for ground transportation services was also found to be inadequate. One traveller spent hours in Toronto trying to find the proper bus because of inadequate signage.

Going through Security was another area of concern. Inexperienced travellers may end up very confused if they are unaware that hearing aids set off the alarm. There is no signage at security that warns travellers who may be using a hearing aid.

Waiting at the Boarding Gate raises concerns for most travellers. Once travellers get to the right gate, there can still be some problems, particularly at multi-gate boarding areas. One traveller shared her experiences: *"I'm constantly asking if this is the flight to Vancouver or Toronto because I can hear them talking on the PA system, but I can't understand what they are saying. I've actually gotten on a plane late, being there bright and early, but I didn't hear the boarding announcement."* Another traveller said that a flashing light at the gate to indicate boarding would very helpful.

Customs and Baggage Pick-up present problems for travellers with hearing difficulties. Customs is a problem in the same way that checking-in is a problem -- agents often don't speak loudly or clearly enough. The problem with baggage pick-up is that the announcement about the flight's corresponding baggage carrousel is usually made as the traveller is deplaning and can't be understood if one is hard of hearing. *"I spotted this fellow on my flight and I just kept my eye on him. I had no idea where I was going. I was thinking I hope this guy's got luggage..."* The sign over the carrousel indicating the flight numbers is not always correct.

Emergency Situations and Announcements was the last process cited as a concern. Focus group participants expressed concern over the possibility of not hearing verbal announcements in emergency situations. At present, the notices about emergency procedures in the airports are difficult to find and even more difficult to understand. The group did not feel, however, that a loop system would be much help in an emergency situation. *"... you can be sure that if I was sitting in a lobby, and I saw people rushing about, boy I would be up and about making sure I knew what was going on. I wouldn't wait and just read my book and tune right out, I mean I would not feel comfortable totally relying [on the loop]".*

Assistive Listening Systems

All participants at the focus group session expressed the belief that the use of loop systems has improved their ability to communicate and their ability to play a more active role in society. *"I think they're wonderful and I think they're the way to go. It really opened the world for me in the sense of being able to hear".* Everyone agreed that loop systems could have a useful application in an airport.

Generally, the group agreed that an FM radio system would not be as effective as an induction loop system. Hearing impairment is an invisible disability; but, if an FM system is used, travellers will have to wear a receiver around their necks and the disability will be made visible. The group agreed that many travellers who are hard of hearing, especially those with lesser degrees of hearing loss, would be reluctant to use the receivers. Furthermore, the group felt that people who are hard of hearing should be encouraged to use hearing aids with T-switches. There is a tendency for people with lesser degrees of hearing loss to use 'inner ear' aids which are usually too small to accommodate a T-switch. If, however, assistive listening systems were in place which require a T-switch (such as loop systems), travellers who are hard of hearing will all want T-switches to improve their ability understand. At present, many travellers whose hearing aids do not have T-switches turn the aid off when they are in the airport because the environment is so noisy that they can't pick up any auditory information anyway. If they could turn their aids to T, then they would be able to pick up valuable information which would assist them in negotiating the terminal. The one concern that was expressed about the installation of loop systems was that the amplifier be strong enough to accommodate the people with very severe hearing loss.

Location of Loop Systems

A lot of time in the focus group session was spent discussing appropriate locations in the airport for induction loop systems. It was agreed that it would be impractical to loop the whole airport because different information is required at different locations. Small, isolated loops would also have little value. Participants did not think it would be useful to loop an area around an orientation map, for example, because travellers would not be there for very long.

Everybody agreed that it would be very useful to have one **ticket purchase/check-in counter** for each of the major airlines looped. Improved training for air travel personnel has often been recommended as a means of alleviating the problems of travellers who are hard of hearing; however, there does not appear to be much improvement in this area over the years. It would seem that the installation of a loop system would make communication easier for both the agent and the traveller and would reduce the time and cost of training agents in signing, proper speaking techniques or other communication techniques. Some discussion (length of line-ups, self-identification, stigmatism) ensued as to the possibility of an exclusive counter for individuals with a hearing loss, but no conclusions could be drawn.

Another area which people thought a loop system might be useful was at a specific waiting area, in which all the PA announcements would be on a loop system and could be picked up in the area. This could be all the **washrooms, the cafeteria and the waiting area**. One participant said *"If you could section off an area that was looped, and I would sit there, put my hearing aid on T and just have a ball. I would listen to every announcement and wait for the one I needed"*. One participant, however, had an opposing view: individuals with only one hearing aid which is switched to the T-coil would be unable to pick up noise cues about what is happening or other outside information; for example, they would not be able to have a conversation with a fellow traveller -- increasing instead of lessening feelings of isolation. *"If I put my T-switch on I'd miss out on having a conversation so I'd be isolating myself even more, but if I could talk to somebody, as I normally do, and I had the visual information, then that would solve most of my problem"*. For people with two hearing aids (which is not an unusual situation), this is not a problem because they can turn one aid to T and the other to M and be able to pick up sounds around them. If these areas were looped it was suggested that it wouldn't reduce the need for better visual presentation of information. A visual display of flight changes and delays would still be necessary.

It was agreed that loop systems at each of the **boarding gates** would be extremely helpful. This would solve the problems associated with not being able to hear boarding announcements -- problems such as missing the plane or getting onto the wrong plane. It was suggested a loop system might also benefit the general public. Often the boarding areas are very noisy and announcements are hard to understand for the general public. Receivers could

be made available at the gates to whomever wanted one, and could be picked up again while boarding. Caution was expressed however that improperly-used receivers can damage hearing. Instruction on how to use the system would have to be given if the system was open to the general public.

Participants in the focus group did not think that loop systems would be very useful for helping in baggage retrieval procedures, even though the information about where is to pick up baggage is often given over the PA system. The feeling was that travellers are not in one place long enough to be able to benefit. It was suggested instead that visual cues be improved. A digital message along the hallways or in the baggage retrieval area would be very helpful. Some participants thought that for international flights, a loop system in the customs line area hooked up to the PA system would be useful. Information about baggage retrieval as well as paging announcements could then be picked up by the hard-of-hearing traveller.

It was felt that loop systems should not be relied on for emergency situations either because loop systems are localized. Travellers not in the looped area, or without their aid switched to T would not be able to pick up the information. All participants agreed that emergency situations should be conveyed by visual cues including flashing lights and possibly a digital visual display.

Participants also didn't feel that it would be necessary to have a loop system for inquiring about hotel accommodation or ground transportation. These procedures, however, would be much easier if more TDD's were available and more T-mode phones were available in locations where these procedures are carried out.

APPLICATIONS TESTING

Although loop systems were very well received by the hard of hearing and appear to have a useful application in travel terminals, a technical evaluation of both the loop system and the FM radio system (Phonic Ear transmitter 471 and 475 receiver) was conducted to determine the technical feasibility of loop systems in the Vancouver airport terminal. These tests were conducted in locations identified by the task analysis and focus group sessions as possibly benefiting from an ADL system.

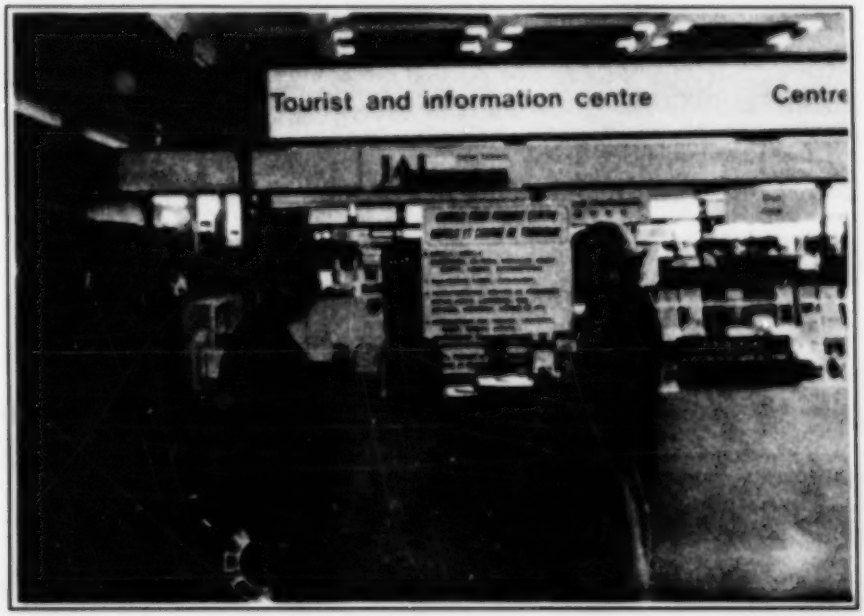
The technical testing of the potential applications was conducted by Doug Clifton, supervisor of the Technical Aids Department at the Western Institute for the Deaf and Hard of Hearing (WIDHH) and Marion Rosenburger, Audiometric Technician from WIDHH, with guidance from the researchers. The Superintendent of Terminal Services at Vancouver International Airport and her staff were also very helpful. All airport and airline personnel affected by the tests expressed interest and were most co-operative. Five main areas were tested within the airport terminal and these are discussed in the following paragraphs. Maps and photographs are included to facilitate understanding.

Information Map (Area 'A')

The first area tested was on the third floor departures level of the terminal, near the information centre and orientation map. This is a high traffic area since it is near the escalator to the arrivals level. Most people using this area stand directly in front of the map to get the information needed.

The loop was laid out around the map itself to enclose the whole information area. The signal was very clear and very little interference was experienced. To loop this area permanently, the loop would either need to be put in a groove in the concrete floor and covered with silicone, or placed on the ceiling. Providing that the access to the PA system and connection to the loop is relatively easy, the loop system would be adequate. When the loop was placed close to Communicaid, a lot of interference was experienced. The fluorescent lighting and electronics for the computer system are not compatible with the loop system. It would therefore be impossible (and most likely not necessary) to have a loop system within Communicaid.

Exhibit 10: **Testing of the Loop System at Vancouver Airport**



Doug Clifton discusses proposed procedures with Anne-Kristina.

The FM system in this area picked up a lot of background noise, although the range was very good. Connecting the system to the PA in this area would be more difficult than for the loop system because the antenna for the FM would have to be pointed in the direction of the users. This may be difficult as the area is very long and rectangular. Another difficulty arises in consideration of distribution and collection of receivers. The information counter could be responsible for the receivers; however, the counter is often closed in the early morning and late evening posing a problem for travellers on late flights.

Boarding Gate (Area 'B')

The second area tested was a boarding gate in the east wing of the terminal. The loop was laid out around the waiting area including the washrooms. As long as the traveller was within the loop, the signal was very clear, even within the washroom area. A concern was the proximity of different gates within the wing. However, it was found that the signal could not be picked up on the transmitter by the technicians at another gate 10 feet away. Interference between systems at different gates should therefore not be a problem. Installation of the loop systems would not be difficult at the Vancouver terminal because the gates have false ceilings which are low enough for users to be able to pick up the signal. The loop would be connected to each individual PA system in each gate so users would hear announcements within each gate only. It would appear therefore that a loop system would be effective in terminals where the gates are close together.

Exhibit 11:
Testing of the Loop System at the Boarding Gates

Doug Clifton speaks into the microphone, Marion Rosenburger checks magnetic flux meter and listens.

The FM system was also tested at this gate. Within the one gate the system was clear will little interference. However, in situations were several gates are close together, the transmission of the signal from one gate would interfere with the other. This could be overcome by having each gate at a it's own transmission frequency. The distribution and collection of receivers would be much more easily controlled at a boarding gate than in the main terminal area. Installation of the FM system for the gate would be done in much the same way the loop system is connected. The FM would be connected to each individual PA in each individual gate.

Boarding Gate (Area 'C')

The third area tested was a boarding area on the west wing in which four gates are located in one area of approximately 10,000 square feet (an area similar to the Ottawa airport). The loop system was not tested at this site because the room was too large and there was too much traffic (people might have tripped on the loop wire). To loop the whole area would not be effective in such a large area unless the wire could be crisscrossed across the room to fill holes in the system. To do so would also require a very large power source. Of course, only one (or several) small areas may need to be looped, depending on the operation of the gate. For example, if the area serves four gates, four small loops might be more effective in meeting the needs.

The FM system was tested and worked very well throughout the whole area. If the whole area is to be covered, the FM system might be more practical. In this area, there could be control of the distribution and collection of receivers, upon entering the gate and boarding, making it feasible to use an FM system here.

Baggage Retrieval (Area 'D')

The fourth area tested was on the arrivals level, second floor of the terminal, near the baggage retrieval and information counter. Results were very similar to those found in Area 'A'. Both the loop system and FM system signals were very clear. It was important at this point, to test whether there could be any interference between floors if loop systems were placed on each floor. There was no interference between any of the floors when this was tested.

Exhibit 12:
Testing of the Loop System near Baggage Retrieval

Doug Clifton speaks into the microphone while Marion checks the quality of sound.

Customs Area (Area 'E')

The last area which was tested was the customs area on the first floor. The signal from the loop system was very clearly received in this area. Installation would be easy since there are false ceilings in this area. The FM system was also very strong in this area, however; distribution and collection of receivers in this transient environment would be a concern for operating personnel.

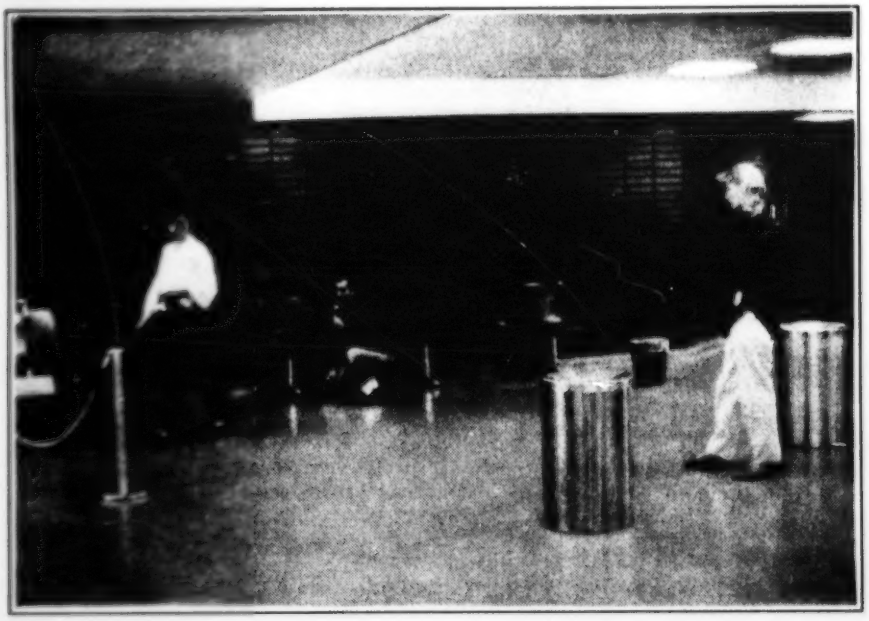


Exhibit 13:
Testing of the Loop System near the Customs Area

Doug Clifton speaks into the microphone while Marion and Anne-Kristina Arnold listen.

PROPOSED APPLICATIONS

The task analysis indicated stages of the travel process where hard-of-hearing travellers may encounter difficulties because information is only present orally. These stages were: at the information counter, at the check-in, when purchasing a ticket, going through security, when boarding, in customs, listening to announcements, phoning to arrange a hotel, and when communicating with ground personnel to determine schedules.

The focus group sessions highlighted stages which are particularly difficult for the hard-od-hearing traveller. These include: the check-in counter, purchasing a ticket, listening to announcements, and communicating with ground personnel. Wayfinding was not particularly difficult but, when signage is poor, the hard-of-hearing traveller is a disadvantage. This highlights the importance of good signage and wayfinding cues.

The testing of these systems shows that technically, there are applications for both FM and Loop systems at different locations within the terminal. Although an FM system works quite well in most of the areas, the distribution and collection of receivers creates such a difficulty that the use of the system becomes prohibitive. The loop system works very well in all but one of the areas tested and would therefore appear to be the best system to use.

The conclusion from this investigation is that there are three main areas within an airport terminal where different types of information are required and where a loop system would be most useful to travellers who may be hard of hearing:

1. **Around a Ticket Purchase/Check-In Counter** where travellers with hearing impairments experience a lot of difficulty understanding any verbal information exchange. It is suggested that the loop system be hooked up directly to a microphone into which the agent would speak. This will help clarify any mis-communications between the agent and the traveller.

2. **In the Waiting Area/Cafeteria Area** since the major concern of travellers with hearing impairments is missed information about flight changes and delays. In this area, the loop could be connected to the main public address system to obtain information about flight delays, gate changes, paging information and emergency procedures. Visual information of public address announcements should also be improved to accommodate many other travellers who can't or won't be able to use the loop system.

3. **At the Boarding Gates** where travellers with hearing impairments have particular concerns about missing information about the flight spoken by the gate attendant. In this case, the loop system could be installed around the waiting area and connected to the gate's public address systems. It would transmit information from the gate agent about boarding procedures. At some gates, the loop could also be placed around the washroom areas.

If loop systems are to be placed in transportation terminals, a concern arises about how to convey that the system is available in different areas. Some solutions arose from the focus group discussions. Firstly, it was suggested that the blue access symbol could also be placed in each looped area including over the designated ticket purchase/check-in counters. Another suggestion was to slip a piece of paper in with each boarding pass given to hard of hearing passengers to indicate areas which are looped and how the system works. A third suggestion was that a map of the terminal could be printed on each boarding pass. The map would also indicate which areas of the terminal were looped.

5. REQUIREMENTS

Ideally, in a transportation terminal, anyone who is hard of hearing should be plugged in directly to the PA system so that they receive only the sound from the speakers minus crowd reverberation and without the terminal noises. In the past some attempt has been made to do this in certain halls and theatres where a section would be reserved for people with hearing impairments, with a number of audio outlets for headphones.

Such arrangements were fraught with problems. One was that the users might have to be segregated from their friends, which made them self-conscious. Another was the constant damage done to the headphones and wiring; it was common for users to forget they were wearing headphones and stand up and move away while still connected. Yet another problem was the regular disappearance of loaned headsets.

All these drawbacks can be overcome by the installation of a magnetic loop around the periphery of the area which is fed from the PA system. The PA output can then be received by anyone with a suitable hearing-aid within the area. So there is no segregation, the users can sit where they like; there is no wiring or connections to worry about so no maintenance problems; and the users can still hear if they move from their seats.

What then about the receivers? Many North American hearing-aids have a selector switch which has two positions marked M and T. In the M position, the internal microphone is switched on for normal usage. The T position is for telephone use and it disconnects the microphone and switches in an induction coil. This responds to the magnetic field of some telephone ear-pieces and thus enables the user to hear the telephone without double transduction, that is

sound generated by the ear-piece being converted back to an electrical signal by the hearing-aid microphone. This greatly improves the quality and intelligibility of the sound heard.

When switched to the T position, the normal hearing-aid becomes an ideal receiver for a magnetic induction-loop sound system. The coil is mounted vertically, which is in the same planes as a loop wired around an area, and so achieves maximum signal pickup. From the management's point of view, this means no separate hearing devices to be supplied, with their repair liability and disappearance.

From the user's standpoint, there is no fuss over having to obtain and return an aid. The aid can be switched from normal to T at the start of the performance and back again at the end, in an instant. All extraneous noises are cut out, in fact in some cases users can hear better than those with normal hearing. A further big advantage is that the volume can be individually adjusted to suit the particular user, as he or she would do when using the aid normally.

LOOP DESIGN REQUIREMENTS

Designing and installing a loop is probably best left to professional audio contractors and/or consultants. Some design requirements are mentioned in this chapter, however, to provides some knowledge for use in procuring or checking a commercial product or installation. Designing a loop is reasonably straightforward, being a matter of taking the area to be covered and the length of the longest side, then calculating the cable resistance, number of turns, and amplifier power to produce the required field strength.

Strength/Shape of the Loop

The ideal strength is that which presents a signal to the hearing-aid which is comparable to the output of the internal microphone. Too weak a signal is not desirable as this would mean users having to turn the gain well up, which would make the noise of the internal amplifier noticeable. There is an international standard which specifies the optimum strength as 100 mA in a single-turn loop of 1 metre diameter:

> *"The field strength within the loop shall equal 100 mA/m ±3dB, with 70 mA/m as a minimum and 140 mA/m as a maximum, intended as the average value of the vertical component of the field strength inside the area enclosed by the loop, measured at 1.2 m above the floor."* [IEC Spec 118-4]

This highlights a basic factor, that it is the current and the number of turns that influence the resulting field in any given size of loop. Because the hearing aids will require negligible power from the magnetic field, the voltage required is only that needed to drive the required current through the resistance of the loop. If the resistance can be made very low, the necessary current can be achieved with only a small voltage, hence with minimum power. However, as the field

strength is proportional to the product of the current and the number of turns, it can be an advantage to increase the turns even though this also increases the resistance. More turns also, unfortunately, cause losses on the higher frequencies and consequently degrade the audibility.

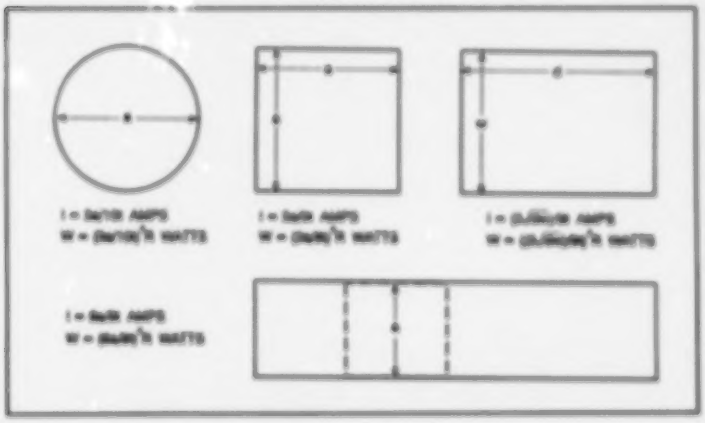
The specified current of 100 mA/metre is for the average signal, but peaks will exceed this. The IEC Standard recommends allowing for peaks of 12dB above average, which increases the current requirement by four times. If dynamic range compression is used in the feed amplifier, this could be reduced. However, if the system is to be used mainly for speech, then much lower peaks need be accommodated. In practice, allowance for 6dB peaks, or twice the average, has been found to be adequate. However, to ensure a good safety margin, the following calculations assume peaks of 10dB.

If the average current in amps is $a/10$ (where a is the diameter of the loop in metres), the peak is $3a/10$. With the exception of Albert Hall in London, England, few halls are circular. A square loop needs slightly more current to provide the same field, about 112 mA for a square of side 1 metre, so the formula becomes $I = 3a/9$ amps.

Most halls, however, are rectangular. Doing the calculation properly would be complicated, but for practical purposes we can work out a close figure for halls with a length of no more than 1½ times the width. This can be done by multiplying length and width to give the area, then finding the square root to give the side of a square of equal area. So our formula becomes $I = 3\sqrt{dw}/9$, where d is the length and w the width.

In most cases the effect of shape has little effect on the design. In the case of long narrow areas, things are rather different. With a square loop, each side contributes equally to the field. But if we take a square section, somewhere near the middle of a long narrow loop, the sides are too far way to have much effect. So only two of the four sides of the square are generating any field. Hence the field is approximately half what it would be with a square loop of the same width in the central portions, rising to around three-quarters in the parts adjacent to the sides. The lesson is to avoid long, narrow loops.

Exhibit 14: **Current and Power for Loops of Various Shapes**



In general, except for long and narrow loops, the effect of shape is probably the least important variable to consider. Minor detours around doors and windows are easily accommodated during design.

Field Distribution

When designing an induction loop, the magnetic field and its distribution is a concern. If the loop is level with the receivers, starting at centre, the vertical component of the magnetic field rises gradually as you move towards the loop itself. At about halfway between the centre and the loop, it rises dramatically to about +22 dB, at a point close to the loop. Then it drops to a null point outside the loop. Beyond this, further outside the loop, it rises again to about +10dB, then falls linearly. This is shown by the solid line in Exhibit 15.

Obviously, this is not entirely satisfactory, as there are wide differences in field strength across the loop which would call for different gain levels in the user's hearing-aids according to their positions. If instead, the loop is displaced vertically so that it is above or below the level of the receivers (hearing-aid coils), the distribution curve is more even. Exhibit 15 also shows field distributions for displacements of one-tenth, two-tenths and four-tenths of the loop width.

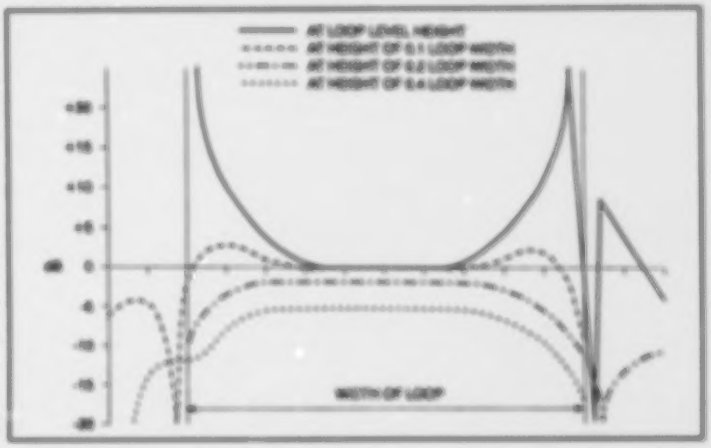


Exhibit 15: **Field Distribution for Different Height Induction Loops**

Of all these curves, the one obtained from the one-tenth displacement is the most satisfactory, and usually it is the most convenient. For an area 10 metres wide, the required displacement will be one metre. For seated users, this would put the loop near the floor, which is fairly practical. It could be at floor level, especially if the hall is wider, as the positioning is not that critical. The loop could just as well be run above the hearing-aid level, and in some cases this may prove to be more practical.

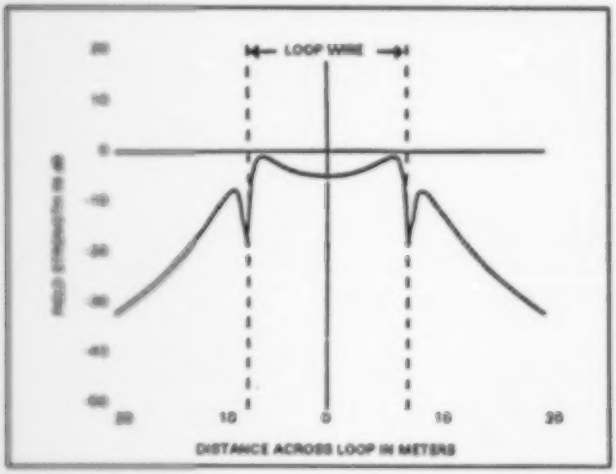
Vertical displacement of the loop from the level of the receivers causes a lower signal which should be compensated for by an increase in the loop current, hence power supplied by the amplifier. Exhibit 16 gives the ratios of displacement in units of loop-width with the multiplying factors for current and power. For the one-tenth displacement, the power is only 1.2 times. For larger displacements, the power requirements increase drastically -- further reason for keeping the loop to the one-tenth level.

Ratio h/a	Multiply current by	Multiply power by
0.1	1.10	1.2
0.2	1.25	1.6
0.3	1.50	2.3
0.4	2.00	4.0
0.5	2.50	6.3
0.6	3.25	10.6
0.7	4.25	18.0
0.8	5.50	30.2
0.9	7.00	49.0
1.0	8.50	72.2

Exhibit 16: **Effect of Displacement on Power Needs**

Null and Overspill

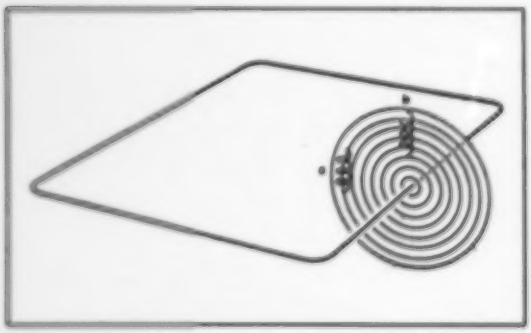
Exhibit 17:
Field Distribution Across the Loop



The pattern of the field created by the loop is weakest immediately above/beneath the wire and most consistently stronger near the centre; therefore, it is best to meake the loop as large as practical to assure the intended audience is well within the perimeter. An infreqent concern is 'overspill' beyond the loop (generally equal to half the diameter), causing adjacent loops to interfere with each other.

It may be wondered why there is a null point as the receiver passes over the loop, or at greater height, just beyond the loop. It is not that the total field disappears, just the vertical component. If the receiver coil is placed horizontally instead of vertically, then there will be maximum pickup over the loop wire, and minimum within the loop, the opposite of normal. Users may actually notice that the sound fades out to zero when they bend down to pick up something from the floor. This is, of course, because the hearing-aid coil is tilted through 90° to the horizontal when you bend over.

Exhibit 18:
Null and Overspill



Overspill (the magnetic field outside the loop) is unaffected by normal building materials, but falls off linearly with distance. Beyond about a quarter of the loop width, it drops to too low a level for practical use. Even this, though, can be useful. During our tests, a delighted researcher related how she could still hear what was going on during a visit to the washroom.

In general, therefore, a large loop is likely to provide a more uniform signal, overcoming the vagaries of hearing aid telecoils. But, the larger the loop, and the farther a listener might be from the loop, the more energy (amplifier power) is needed in the loop for a satisfactory signal; with too large a loop or an amplifier with too little power, a loop might be 'dead' in the centre. An 80-meter loop would enclose an area 20 meters by 20 meters (400 square meters) which should be fine for most areas at the airport. Waiting areas might, in fact, be enclosed by a loop one-half this size.

Choosing the Cable

To meet the field strength requirements specified in the IEC Standards of 100 milliamps per meter in a square loop, the required current was calculated to be *3a/9* amps. Loops, however, can consist of a single strand of wire or, in some instances, several turns can be used to advantage. As you would expect, the current required is divided by the number of turns, so the formula becomes *3a/9t* for a square loop (where *t* is the number of turns).

Added turns increase the induction of a loop, producing a stronger signal. It is therefore possible to achieve an adequate signal with a less powerful amplifier by including extra turns in the loop. But, with too many multiple turns, there can be some 'coupling' which may impair transmission of high frequencies. Also, high frequency response (especially important for most hard-of-hearing listeners) is rapidly lost when loop inductance becomes too great.

A convenient method of wiring multi-turn loops is to use multi-conductor cable and connect the conductors in series -- end to end -- using a junction box or terminal strip. Thus a single loop of standard three-conductor cable gives a three-turn circuit without actually running three separate turns around the area. Exhibit 19 illustrates the method of joining a standard three-conductor cable together to ensure that the current goes around the loop three times, begining at the black wire and ending at the red wire.

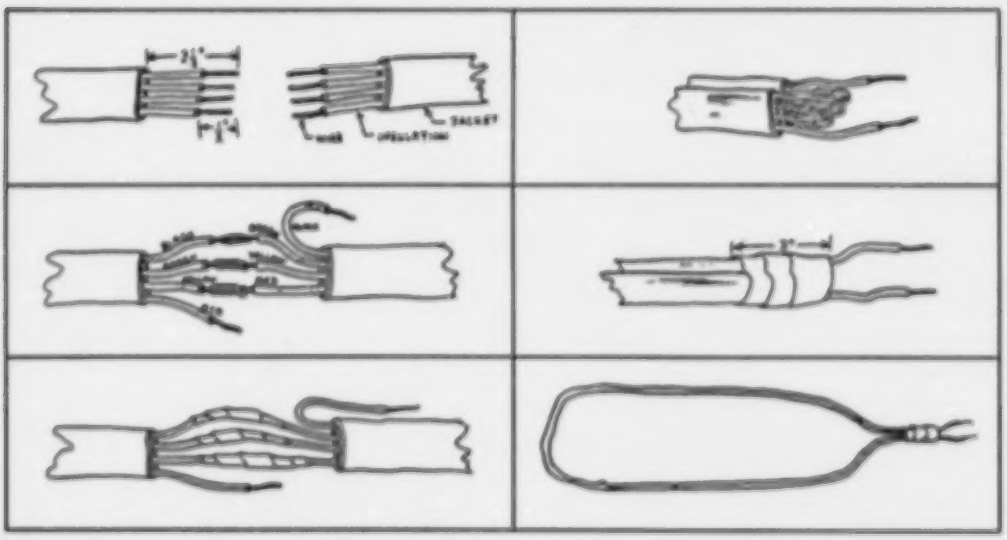


Exhibit 19: **Wiring a Loop in Series for Multiple Turns**

The free ends of the black wire and the red wire would then be connected to the audio amplifier -- the red wire to the proper impedance outlet on the back of the amplifier (8-ohm output in this example) and the black wire to the 'COM' connector. Other connections are discussed on the following pages.

Determining the Impedance

Now we must match the loop resistance to the output of the amplifier. If a separate amplifier having a four-ohm output is used, the loop should equal this or be a little higher, say five ohms. This is about the lowest resistance that can normally be matched to a standard power amplifier. The resistance should be a little higher than the rated impedance of the to avoid the potential danger of fire or amplifier damage should overload occur).

Exhibit 20: **Resistance of Some Common Wires**

AWG (Copper)	Resistance per 100m	Safe Length
12	0.52	200
14	0.83	180
16	1.32	140
18	2.09	100
20	3.33	90
22	5.30	80
24	8.42	60
26	13.39	50

Exhibit 20 gives the resistance per 100 metres of a single wire of various gauge cables. One of the most commonly used is 20 AWG, three conductor which has a resistance of 3.33 ohms per conductor or 10.0 ohms total. The heavier gauge 18 can also be used if the run is long and resistance high as a result; its resistance is 2.09 ohms per conductor or 6.27 ohms total.

The first step, then, is to measure the total length of the run. This must include detours around obstacles and recesses. For a medium-sized area, a run of around 80 metres is a common average. This gives about 8 ohms for 3x20 AWG which matches nicely with an 8 ohm output amplifier. Any value below this needs a 4 ohm output, even though it may be closer to 8 ohms, because the load should never go below the rated impedance of the amplifier. It is a matter of juggling the gauge and number of turns to produce the desired resistance of the measured length. Adding a series resistor to make up a value, not only wastes power, but may have an adverse effect on loop performance.

Swamping Resistance. If a series resistor is required to match the amplifier output, 'swamping resistance' is added. This is simply the addition of resistors in series with the loop having a value of the difference between the resistance of the loop and the target amplifier impedance. The resistance of the lead connecting the loop to the amplifier should be considered as part of the swamping resistance. Be sure to use resistors whose total wattage rating is at least equal to the maximum power of the amplifier. Typically, these are housed in a well ventilated box connected to the amplifier speaker output, which might also contain a VU meter, auxiliary speaker volume control, and a jack for connecting the loop itself. Swamping resistance is sometimes added to achieve a desired corner frequency.

Corner Frequency. Another consideration for the loop design and construction is a factor called 'corner frequency'. This is the desired audio frequency needed to provide satisfactory listening within the loop. Generally, the voice spectrum covers the range of 100 to 5000 hertz. The higher ranges are particularly important for listeners who are hard of hearing. A corner frequency of 3 kHz would provide minimum voice quality and 6 kHz would provide excellent quality. The actual corner frequency can be determined by the formula: $F = 3a/9t$.

Amplifier Power

Although the production of the magnetic field is not a function of power out of current alone, a certain voltage is required to produce the necessary current, hence power is expended. So, what power will be needed from the amplifier?

Ohm's Law states that $I = V/R$ where I is the current in amperes, V is the electromotive force in volts, and R is the resistance in ohms. Power is measured by the watt and the formula for calculating power is $W = I^2 R$, where the power in watts.

Combining this with the earlier formula, we get:

$$W = (3a/9t)^2 R$$

If we remember that R depends on the number of turns, and write $R = rt$, where r is the resistance per turn, then we can re-write the formula as:

$$W = (3a/9)^2 (r/t)$$

which shows that the more turns we use, the less power is necessary to drive the loop.

Let us look at an example to illustrate. Supposing a hall having 20m as its width and needing 80m of cable to enclose, is wired with 20 gauge wire. The resistance for a one-turn loop would be from the table, (80/100 x 3.33) or 2.66 ohms; for a two-turn loop the resistance would be 5.33 ohms; and for a three-turn loop, 7.99 ohms. For the two-turn loop we have:

$$w = ((3x20)/(9x2))^2 \times 5.33 = 59 \text{ watts}$$

And in the case of the three-turn loop, the required amplifier power is:

$$w = ((3x20)/(9x3))^2 \times 7.99 = 39 \text{ watts}$$

These two examples are illustrated on the accompanying audio induction loop design chart on the opposite page. As show in the exhibit, the more powerful amplifier would provide better speech quality since the corner frequency would be higher (around 4 or 5 kiloHertz).

With 18 gauge wire, the resistance for two-turns is 3.34 ohms. The three-turn cable has a resistance of 5.02 ohms. So using the above formula we have:

$$w = ((3x20)/(9x2))^2 \times 3.34 = 37 \text{ watts}$$

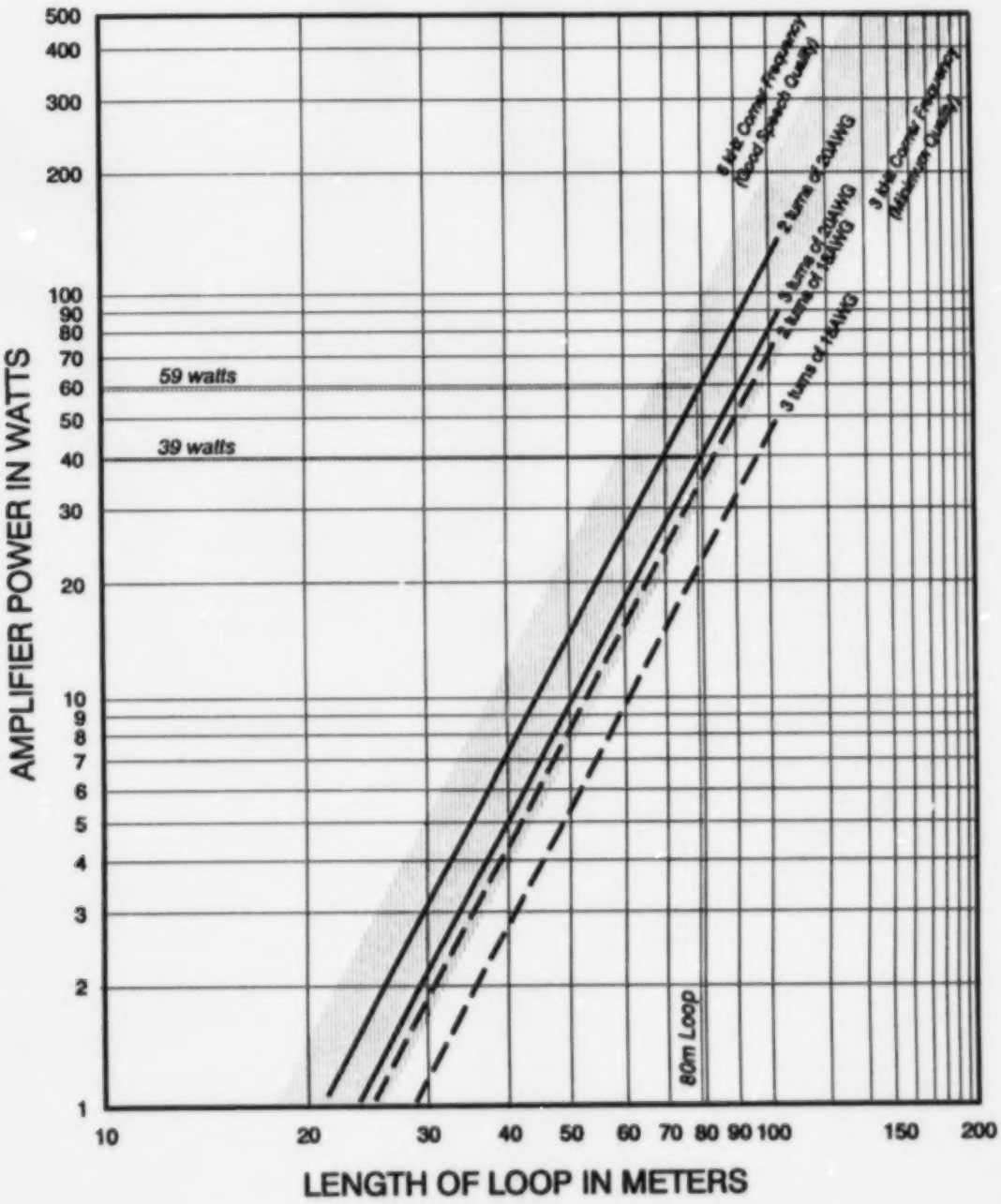
two-turns, and for three-turns:

$$w = ((3x20)/(9x3))^2 \times 5.02 = 25 \text{ watts}$$

With this gauge of wire, however, even though the power required from the amplifier is lower which may be an advantage, the quality of sound produced by the loop would be poor and the quality of speech heard by the listeners would not be very good.

On the audio induction loop design chart, power requirements for additional gauges of wire (or constant impedance factors) could easily be calculated and drawn. For clarity, however, only a couple of wire gauges were drawn.

Exhibit 21: **Audio Induction Loop Design Chart**



Amplifiers

A separate amplifier fed from the 'line out' socket of the existing PA amplifier is the most flexible and satisfactory means of supplying a loop. The power rating can be chosen from the formula already described. However, in transportation terminals, it is more likely a feed from the output of the PA amplifier already installed will be taken.

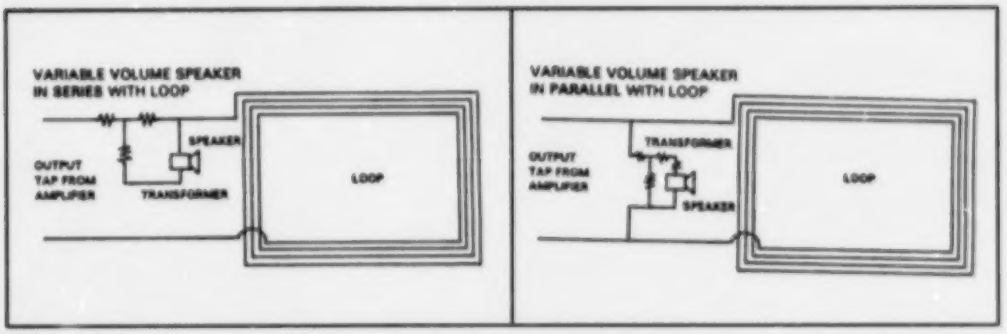


Exhibit 22: **Series and Parallel Connection of Loop to an Amplifier**

If it is a proper PA amplifier, it will have a 100 V output tap, and this should be used with a suitable matching transformer. The main requirement is that the amplifier has sufficient power to supply both the loop and the speakers. With many PA systems there is an ample reserve; it is not uncommon to find 80-100 watt amplifiers feeding speakers tapped at 25-40 watts.

The 100 V output is the output voltage obtained when the amplifier is delivering its full rated power. From the formula:

$$Z = E^2/W$$

it can be seen that the actual impedance of this tap depends on the wattage rating of the amplifier; for a 50-watt amplifier it is 200 ohms, for a 100-watt, 100 ohms and so on.

The transformers used for matching PA speakers to the 100 V output have a secondary rating in ohms: 4, 8, 16, or often all of these via tappings. These are connected to a speaker of the appropriate impedance. The primary has tappings rated in watts so that when a particular tapping is selected, the specified wattages will be taken from the 100 V output and fed to the speaker.

So you can have a mixed bag of speakers all set to different powers to suit different locations in the PA system, and the only calculation necessary is to add up all the tappings and make sure that the total does not exceed the power rating of the amplifier.

The loop is taken to the appropriate secondary tapping on the 100 V transformer, and the primary tapped to give the required wattage.

TESTING REQUIREMENTS

Experts advise against testing by people who are hard of hearing because of the differences in hearing and aids. There is also a real danger of subjectivity. Rather, they propose using a field strength (magnetic flux) meter (not commonly available) which is calibrated over the voice spectrum of 100-5000 Hz. The objective is to meet the international standard of 0.1 ampere/meter for an input of normal speech level (0.4 A/m for speech peaks). This field strength produces an audio voltage in most T-coils about equal to the output of the hearing aid microphone.

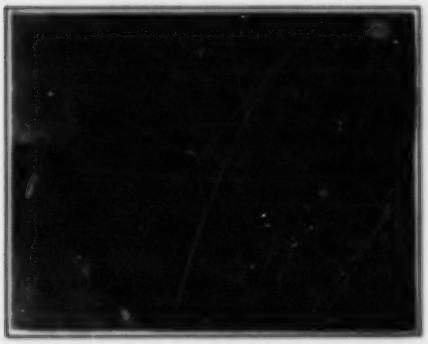


Exhibit 23: **A Field Strength (Magnetic Flux) Meter**

Another valuable use of the meter is to survey the room in which a loop is contemplated *before* the loop is designed and installed. Existing interference patterns can be identified and avoided (e.g., crossing a noisy power line rather than paralleling it or keeping clear of a motor or transformer 'hum').

Because of the variability of individual speech patterns, some suggest that proper testing can be done only with a 'controlled' sound source. A carefully selected (or composed) audio tape, played on a recorder fed into the amplifier would do the job.

Whether by meter or, most likely and generally adequately, by 'ear', be sure to test all areas (inside and outside the loop) where a listener might be expected to sit. Sometimes dead spots cannot be avoided, but they should be identified to alert listeners away from them. If you have not already done so prior to installation, this is the time to check for ambient signals from fluorescent lights, transformers, etc. Typically, there should be no concern for the 60 Hz radiation of ordinary wiring, since telecoils generally are designed to avoid frequencies that low. Another potential for interference is proximity (less than one meter) of the amplifier to an operating video display.

OPERATING GUIDELINES

Volume Monitoring. Amplifiers in transportation terminals would normally have an automatic volume control circuit. In the absence of such, however, it would be desirable to have a person with normal hearing 'ride gain' on the amplifier when it is in use to assure that the volume does not rise to the distortion level. This is easier if the amplifier has a VU meter and/or clipping light (needle in the red zone and light blinking no more frequently than every four or five words). It is important that the person monitoring the sound use an induction receiver, *not* a speaker or earphones fed directly from the amplifier. In this way, what is heard is what those with telecoils will be hearing.

Audience Instruction. Many hard of hearing people are not familiar with audio loops. A special effort must be made to make everyone aware of the loop being in use and the need for them to switch their hearing aids to the 'T' mode in order to take advantage of it. Some installations have a lobby poster or program note. For boarding gates, a hold up sign of some sort does the job better than the common practice of a 'signing' announcement with hand signals shaping a 'T' and exaggerated switching of the aid behind the ear. It helps to remind the audience that, sometimes, a little turn or tilt of the head will place the hearing aid telecoil in better relation to the field of the loop, improving the signal, and/or to increase hearing aid volume. Also caution that, occasionally, a listener will be located too close to an electrical interference (fluorescent light, high voltage line, etc.) which causes an overpowering 'hum' which simply requires moving around until it disappears.

Induction Receivers. With the growing popularity of all-in-the-ear aids, not all hard of hearing people will have telecoil-equipped aids. Therefore, it may be desirable to have induction receivers available for loan. These receivers contain an amplifier and telecoil and take many shapes, sizes and prices. Many problems will occur, however, with distribution, collection, cleaning, repair and control and the potential liabilities of losses and damage to hearing if improperly tuned and used. Therefore, it is not recommended that transportation terminal authorities supply receivers until such time that the demand is too great to resist.

6. CONCLUSIONS

Awareness of the rights of persons with hearing impairments is increasing. The rate of participation of millions of hard-of-hearing people in personal/social, vocational, educational, legal, clinical, cultural and recreational activities is accelerating. Contributing to the changing lifestyles of individuals with a loss of hearing are a number of factors, including various assistive listening devices.

Many persons with hearing impairments use hearing aids. These can be helpful, but they do not discriminate between important sounds and just plain noise. Levels of background noise and reverberation which may be only mildly disturbing to many people can completely obliterate speech understanding for one who suffers hearing loss.

Modern technology provides an answer in several Assistive Listening Devices (ALDs): sound reinforcement equipment specifically designed to facilitate better understanding of speech by persons who are hard of hearing. ALDs include infrared, AM and FM broadcast, and induction loop systems. All systems have one function in common: to eliminate background noise and reverberation.

When sound is taken directly from the source to the ear of the listener, the result is better amplification and clarity of the desired sound, less background noise. A comparison of ALDs was made with respect to existing applications, sound reception, power requirements, receiver requirements, coverage area, flexibility for expansion, and cost of installation. The results suggested that induction loop systems are the most viable system for the proposed application. Nonetheless, because of the advantages of FM radio, both the FM radio system and the audio induction loop system were chosen for further investigation and testing in a transportation terminal setting.

The testing of these systems shows that, technically, there are applications for both FM and Loop systems at different locations within the terminal. It is not recommended, however, that two different systems be used. The confusion that would arise from the use of two systems would make the experience of travelling through a terminal more stressful than it is at present.

The ergonomic assessment of these systems in airport terminal applications has led to some guidelines on how an ADL system in terminals can be of benefit to travellers who are hard of hearing.

The most important finding was that loop systems should be used to convey information in each of the areas chosen, rather than using an FM system or a combination of the two systems. The loop system was found to be the most technically suitable for airport terminal applications and the most acceptable system for users.

GETTING STARTED

Loops are the oldest assistive listening device and are much more prevalent in Europe than in North America. In the Scandinavian countries and the Netherlands, most public rooms of assembly are required to have a loop for access by hard-of-hearing people, and many transit and tour buses are loop-equipped. Fortunately, the momentum is growing here for voluntary as well as mandatory installations. Perhaps with some of the mystery removed by this report, we will see even greater progress.

There is no reason why the techniques outlined in this report can not be applied -- and there is every reasons why they *should* be applied -- to transportation terminals. Canada has the opportunity to be a leader in the use of loop systems in terminals and to set an international example.

PROPOSED APPLICATIONS

The task analysis and focus groups clarified areas in which a loop system may be of benefit to travellers who are hard of hearing. The possibility of putting a loop system around a ticket purchase/check-in counter, in a waiting area and in boarding areas should be investigated. In each of these areas, different information should be conveyed. In the ticket purchase/check-in counter area, the loop should be hooked up directly to the agent's voice. This will clarify any misunderstandings between the agent and the traveller. In the waiting area, the loop could be hooked up to the PA system to transmit information about flight delays, gate changes, paging information and emergency instructions. The loop system at the boarding gate should be laid out around all the seats and would transmit information from the gate agent about boarding procedures. At the gates the loop should also be placed in the washroom areas. During implementation, these areas should be tested for interference and signal clarity.

IMPLEMENTATION STRATEGY

Research and analysis are meaningless without implementation. The technology and expertise are readily available. The benefits are well-documented by organizations for the deaf and hard of hearing. The costs of assistive listening devices are very small. Human rights legislation and amendments to the National Transportation Act mean that the need for hearing assistance systems in terminals is an immediate concern to all terminal operators. All that is required is the will to proceed.

It is recommended that audio induction loop systems be applied to specific situations in terminals across Canada. It is also recommended, however, that implementation proceed slowly, in stages, with sufficient time to evaluate and document system benefits (and unanticipated problems) before providing complete and comprehensive coverage in any particular terminal.

To determine how well loop systems may work in the proposed situations in all airports across Canada, it is recommended that the systems be evaluated in four different airports across Canada: the three busiest ones, Pearson International, Dorval, and Vancouver International; and Ottawa International Airport.

These evaluations should be conducted with a loop system technician. The power of the amplifier required, the length of loop required, and the method and cost of installation should all be noted. In the waiting and cafeteria areas, it is important to know how to get access to connection to the PA system. At each airport the loop system should be tested in a multi-gate situation to check for interference from adjacent loop systems. It is also important to check whether any interference occurs between floors from different loop systems.

In each evaluation, four to six travellers who are hard of hearing should give an evaluation of the system from a user's point of view. These travellers should have varying degrees of hearing impairment. A questionnaire can be used to solicit information about the hard-of-hearing traveller's impressions of the acceptability of the system.

In addition, a simulation should be carried out with 10 to 15 travellers with differing degrees of hearing loss. This can be done in one of the airports. Travellers who are hard of hearing would walk through the terminal as they normally would -- once with loop systems and once without. Different scenarios should present difficulties purchasing the ticket, flight and gate changes and changes in boarding procedures. In the no loop situation, changes should be made as they currently are: over the PA system or from agents. In the loop trial, the information should be presented over the loop as stated above. The traveller would then be asked to comment on each experience. In addition, note would be taken of how well the traveller negotiates the terminal.

This analysis would help to determine the loop system's acceptability.

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